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UNITED STATES
DEPARTMENT OF THE INTERIOR
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BUREAU OF MINES
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MECHANICAL MINING IN SOME BITUMINOUS COAL MINES

PROGRESS REPORT 5. EXTRACTION OF PILLARS WITH MECHANIZED EQUIPMENT

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LOUIS A. TURNBULL AND ALBERT L. TOENGES

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

MECHANICAL MINING IN SOME BITUMINOUS COAL MINES

Progress Report 5. Extraction of Pillars with Mechanized Equipment[1]

By Louis A. Turnbull[2] and Albert L. Toenges[3]

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[1] Work on manuscript completed February 1949. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7527."

[2] Senior mining engineer, Coal Branch, Fuels and Explosives Division, Bureau of Mines, Pittsburgh, Pa.

[3] Principal coal mining engineer, Fuels and Explosives Division, Bureau of Mines, Pittsburgh, Pa.

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INTRODUCTION

This is the fifth of a series of publications that describe methods and practices followed in mining coal mechanically.[4]

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[4] Toenges, Albert L., and Anderson, Robert L., Multiple-Shift Mechanical Mining in Some Bituminous-Coal Mines. Progress Report 1: Bureau of Mines Inf. Circ. 7014, 1938, 56 pp.

Toenges, Albert L., and Jones, Frank A., Multiple-Shift Mechanical Mining in Some Bituminous-Coal Mines. Progress Report 2: Bureau of Mines Inf. Circ. 7067, 1939, 58 pp.

Toenges, Albert L., and Maize, Earl R., Multiple-Shift Mechanical Mining in Some Bituminous-Coal Mines. Progress Report 3: Bureau of Mines Inf. Circ. 7178, 1941, 43 pp.

Toenges, Albert L., Maize, Earl R., and Jones, Frank A., Multiple-Shift Mechanical Mining in Some Bituminous-Coal Mines. Progress Report 4: Extraction of Pillars with Mechanized Equipment: Bureau of Mines Inf. Circ. 7223, 1942, 59 pp.

Many inquiries have been received regarding multiple-shift mechanical mining and the extraction of pillars with mechanized equipment. This paper is concerned primarily with the extraction of pillars and the mining problems incident to this phase of coal mining.

CONCLUSIONS

The curves and conclusions contained in this report are based upon detailed studies of mining operations at 55 coal mines in all of the important coal fields in the United States. Some conclusions have been reached in comparing operations at mines where pillars are extracted and at mines where they are not extracted.

Briefly summarized, the conclusions reached follow: The most difficult problem encountered in pillar extraction is effective control of the immediate roof and the entire overlying strata. It is concluded that the speed and regularity with which pillars are extracted are influential in obtaining regular breaks in overlying strata along established pillar lines.

A comparison of operating data from mines practicing pillar extraction and from mines where pillars are not extracted shows that 6 to 10 percent less coal is produced per mobile loading machine in pillar mining. Similarly, labor employed underground at mines using mobile loading machines in pillar extraction averages 0.22 to 0.25 man-hours per ton more than in mines where pillars are not recovered.

The practice of extracting pillars increases the percentage recovery of coal, and the tendency in mechanized mining is to more nearly recover the entire thickness of the coal bed. It is the objective of these studies to disseminate detailed data relative to the extraction of pillars with mechanized equipment in the hope that more mines will be encouraged to adopt this practice, with the result that the over-all percentage of recovery will improve.

Curves showing the relation of man-hours per ton for mobile loading machines and conveyors to thickness of coal bed mined where pillars are and are not extracted, and curves showing average production per hour of mobile loading devices and conveyors for coal beds ranging in thickness from 20 to 120 inches are at the end of this text following Description of Mines.

ACKNOWLEDGMENTS

The information contained in this report could not have been obtained without the whole-hearted cooperation of the officials of the companies whose mines were studied, and their courtesy and assistance are gratefully acknowledged. Permission to publish these data was obtained from the companies whose operations are described, and the accuracy of the information given was verified by officials of those companies.

A large part of the field work during this study was conducted by E. L. Fish, former mining engineer, and J. J. Dowd and T. R. Jolley, mining engineers, and their assistance is acknowledged.

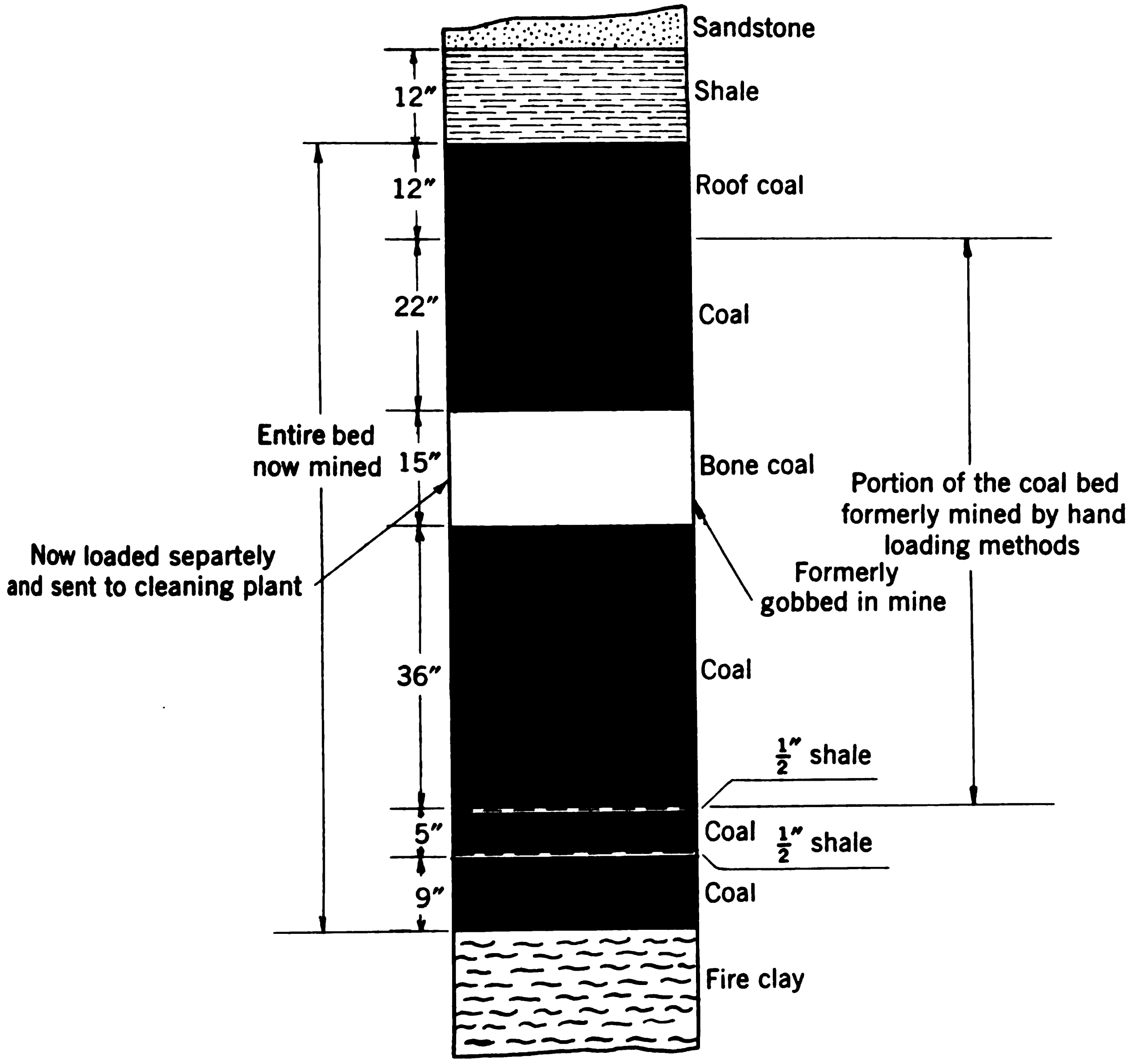

Figure 1. - Section of coal bed at mine 46.

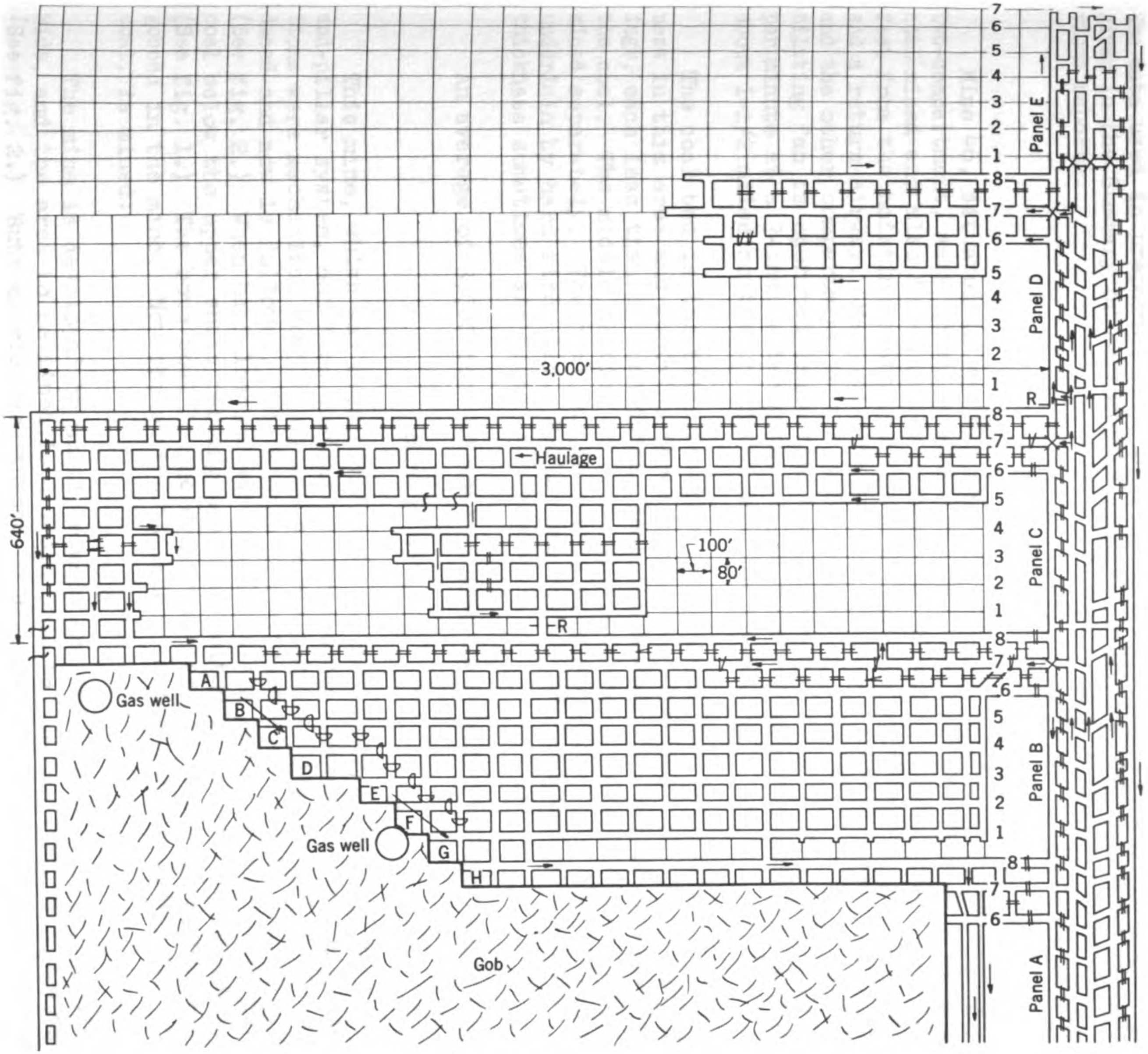

Figure 2. - Mining method at mine 46.

DESCRIPTION OF MINES

Mining operations at mines 46 to 55 are described in this report. Operations at mines 1 to 45 are described in Progress Reports 1 to 4, inclusive. The data used in preparing the curves included at the end of this report are given in the Summary of Performance for each mine described in this and previous reports.

Mine 46

Mine 46, situated in western Pennsylvania, is opened by three shafts. A two-compartment, main hoisting shaft 511 feet deep is used for hoisting the coal mined and also is an intake airway. A second shaft, approximately 200 feet from the hoisting shaft, is divided into two compartments - an intake and a return airway. Men and materials are hoisted in the intake compartment, and the other compartment is the main return air shaft for the mine. The ventilating fan is operated exhausting and furnishes 179,000 cubic feet of air per minute at a 3-inch water gage. A third intake air shaft and escapeway is about 1-1/2 miles northeast of the main hoisting shaft.

The coal bed is the thick Freeport, which averages 100 inches in thickness in this area and contains three partings. (See fig. 1.) Two shale partings, each less than an inch thick, near the bottom of the bed are mined with the coal. The middle parting of bone coal is about 15 inches thick and is mined separately. The coal bed is overlain by hard shale and sandstone and is underlain by hard fire clay. Rolls that reduce the coal bed to unminable thickness sometimes are found in the mine.

An average of 3,000 tons of coal is produced daily in three shifts.

Mining Method

This mine, which was opened in 1917, was developed originally by the room-and-pillar system, and hand loading was practiced. Several years ago, operations were mechanized completely and a block-panel system of mining was introduced and now is followed. The blocks are extracted on retreat from the panels. (See fig. 2.) When hand loading was practiced, 12 inches of roof coal and the coal below the upper shale parting near the bottom of the bed was not mined. (See fig. 1.) The bone coal in the center of the bed was mined separately and gobbed in the mine. Now the entire thickness of the bed, including the bone coal, is mined.

The mine is developed by multiple main and butt entries 12 or 13 feet wide, and the area to be mined is divided into panels 640 feet by 3,000 feet. (See fig. 2.) Butt entries are turned 90 degrees from the main entries and advanced approximately 3,000 feet to the end of the panel. Three headings (6, 7, and 8, fig. 2) are driven through a 200-foot barrier pillar that is left to protect the main entries, and a fourth heading (5, fig. 2) is developed to furnish additional working places for the operating unit. These headings are driven on 80-foot centers, with right-angle crosscuts every 100 feet. The crosscuts between entries 7 and 8, which are haulage and airways, are offset

50 feet from the crosscuts between the other entries in the panel to minimize roof falls, common at the intersection of entries, and make it possible to lay track turnouts right and left of haulage. (See fig. 2.) Crosscuts in succeeding panels are driven in line with the crosscuts between entries 7 and 8 of the preceding panel. Headings 5, 6, 7, and 8 are advanced to the end of the panel, where two crosscuts on 50-foot centers are driven to connect with entry 8 of the preceding panel. The inby crosscut is used as an airway to ventilate gob areas, and the chain pillar between the crosscuts is not mined. The remainder of the panel is developed by driving butt entries 1, 2, 3, 4, and the connecting crosscuts. The unmined coal in a completely developed panel is divided into blocks or pillars 67 by 87 feet.

Extraction of blocks begins at the inby pillar between headings 7 and 8 of the preceding panel. Two operating units are employed in each panel for both development and pillar extraction. The equipment in each operating unit comprises one electric coal drill, one cutting machine, one crawler-mounted mobile loading machine, and one shuttle car or one cable-reel gathering locomotive. The life of a panel is approximately 3 years, and each panel produces about 440,000 tons of coal.

Post-mounted electric auger drills are used to drill the coal in all working places. Both rubber-tired and track-mounted cutting machines center-cut the coal, which is blasted with permissible explosives detonated electrically. Crawler-mounted loading machines load the coal into shuttle cars for delivery to mine car-loading stations and also load directly into mine cars. Fifty-four percent of production originates in a section using shuttle cars for gathering, and 46 percent in another section where cable-reel gathering locomotives are used. Two sizes of shuttle cars are used, 6- and 8-ton, and the average capacity of mine cars is 3.3 tons. Coal is transported in trips by trolley locomotives to the shaft bottom, where the cars are hoisted to the surface on self-dumping cages and the coal is discharged into bins at the preparation plant.

Pillar Extraction

At the time of this study, 50 percent of the coal was produced by retreat mining, and an average of 48 percent of the unit shifts were engaged in pillar extraction. However, 73 percent of the total reserve of coal in a panel is recovered from pillars and 27 percent from entries and crosscuts.

Each panel contains 216 pillars, which are extracted on retreat from the panel. (See fig. 2.) Eight rows of pillars between entry 7, panel A, and entry 7, panel B, are extracted by mining successive cuts from pillars A to H, inclusive. The pillar between entries 7 and 8, panel B, is left in place to protect entry 8, which is a return air course for panel C. These eight rows of pillars are mined by two operating units. One unit operates in blocks A, B, C, and D, and the other unit in blocks E, F, G, and H. (See fig. 2, panel B.)

Each unit mines an average of 2-1/2 cuts in each of four working places in three shifts. This is an average of 3-1/2 cuts per shift and 6-2/3 cuts

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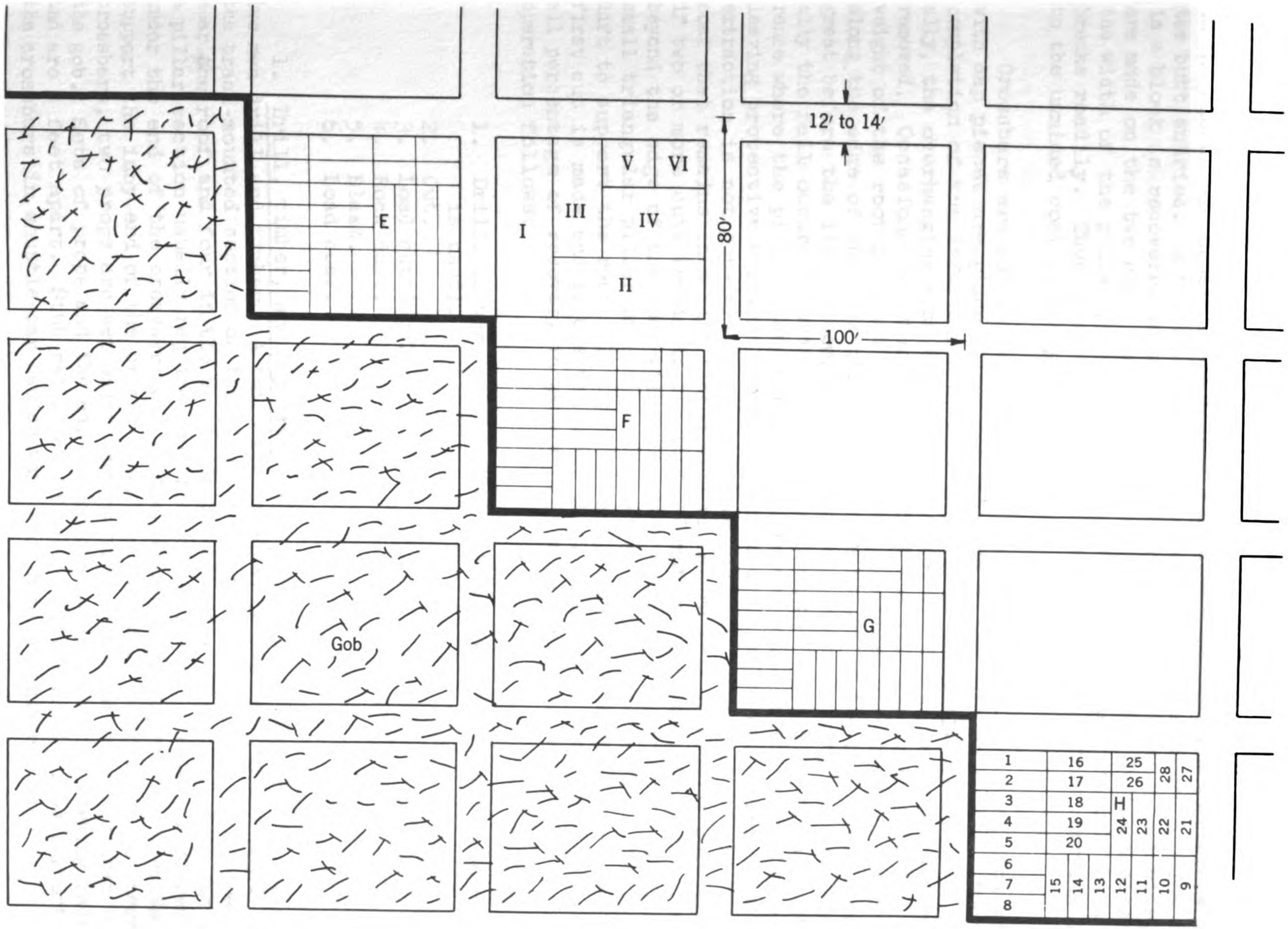

Figure 3. - Timing schedule for loading unit at mine 46.

per shift for the two units in the section. Each block contains 28 cuts. Therefore, 2 units mine 8 pillars (A to H, fig. 2) in 33 or 34 shifts. Cuts in the blocks are scheduled to maintain a uniform pillar line 45 degrees to the butt entries. A typical cutting schedule is shown in figure 3. The coal in a block is recovered in six lifts. Alternate lifts, each 22 feet wide, are made on the two gob sides of the block. The first lift is taken across the width of the pillar parallel to the main cleat of the roof rock which breaks readily. Thus, the weight of the roof is prevented from carrying over to the unmined coal in the pillar.

Crossbars are set on 4-1/2-foot centers in the working places, and props with cap pieces are placed along the gob side of the lift as needed. Upon completion of the lift, the crossbars and some of the props are pulled. Usually, the overhanging rock falls shortly after the timber supports have been removed. Occasionally, when the last cut of the lift has been made, the weight of the roof is great enough to break the props and shear the rock along the edge of the coal pillar. When the weight of the roof becomes too great before the lift is completed, additional props are set, but occasionally the fall occurs before the lift is completed. This is a common occurrence where the pillar line cannot be maintained owing to the necessity of leaving protective barriers around gas wells or in other areas where complete extraction is not possible because of irregularities in the coal bed. The coal that remains in a lift closed by a premature fall is usually recovered if two or more cuts remain in the lift. Sometimes the roof rock fractures beyond the edge of the coal pillar and over the entry or crosscut, and a small triangular pillar of coal is left at the corner of the first cut in the lift to support the roof. This triangular pillar is drilled at the time the first cut is made and is blasted after the lift has been completed. The overall percentage of recovery in panels is 90 to 95 percent. A typical cycle of operation follows:

1. Drill, timber, and lay track (where track-mounted equipment is used).
2. Cut.
3. Load cuttings.
4. Rock dust.
5. Blast.
6. Load coal.

1. Drill, timber, and lay track. - In the trackless section of the mine, two men drill and timber. A third man is added to the crew to lay track in the track-mounted section of the mine. Four holes are drilled in the coal near the roof and four in the bottom of the bed near the floor. Each cut in a pillar section usually requires one 15-foot crossbar. One leg is placed under the end of the crossbar next to the pillar, and two legs are used to support the inby end of the crossbar next to the gob. In addition to these crossbars, two props are set under one cap piece inby the crossbars next to the gob. Sets of props and the cap pieces are parallel to the working face and are 4 feet apart. Stub rails set in holes drilled in the ribs support the crossbars in shuttle-car haulageways and in main haulage roads.

2. Cut. - Cutting machines that are either the universal or slabbing type are equipped with 10-foot cutter bars and cut in the bone coal in the middle of the bed. Two cuts, one in the top of the parting and the other in the bottom of the parting, are made. The cuttings are removed from the kerf by reversing the direction of the chain. Cutter bars are sprayed with water during operation of the machine.

3. Load cuttings. - Approximately 10 tons of cuttings are produced from a 22-foot open end cut. Crawler-mounted loading machines load these cuttings into either shuttle cars or mine cars. Formerly the cuttings are gobbed in the mine, but now this bone coal is loaded and sent to the cleaning plant.

4. Rock dust. - The shotfirer scatters rock dust by hand in each working place before the coal is blasted.

5. Charge hole and blast. - Each of the four holes in the top bench is loaded with one stick of permissible explosive and the bottom holes with three sticks. Sometimes an extra stick of explosive is needed in each of the bottom holes. The bottom bench is blasted first, and the firing order begins with the hole nearest the open side and proceeds toward the solid coal. The top holes are fired in the same order.

6. Load coal. - Crawler-mounted loading machines load the coal into shuttle cars in one section of the mine and directly into mine cars in the other section. Water is sprayed on the coal as it is discharged from shuttle cars into mine cars. A cut in a lift produces about 50 tons of coal. Unit crews for each operation follow:

	Trackless section		Track-mounted section	
	Advance	Retreat	Advance	Retreat
Drillers	1	1	1	1
Timbermen	1	1	1	1
Trackmen	-	-	1	1
Cutters	1	[1]1/2	1	[1]1/2
Assistant cutters	1	[1]1/2	1	[1]1/2
Loading-machine operators	1	1	1	1
Shotfirers	1	[1]1/2	[2]-	[1]1/2
Shuttle-car operators	1	1	-	-
Motormen	[3]-	1	1	1
Brakemen	-	-	[2]1	1
Foremen	[4]1/2	[4]1/2	[4]1/2	[4]1/2
Total	7-1/2	7	8-1/2	8

[1] Cutters and shotfirers in retreat sections prepare for two operating units.

[2] Duties of brakeman and shotfirer combined.

[3] No motorman required. Shuttle-car operator spots cars with remote-controlled spotter hoist.

[4] Foremen responsible for two unit crews.

Studies show that one complete operating cycle in pillar extraction requires an average of 270 minutes. The average percentage of time spent in each operating phase of the cycle follows:

		Percent
Drill, timber and lay track		30.8
Cut		13.2
Load cuttings		6.6
Rock dust and blast		10.4
Load coal		24.4
Delays:		
Transportation	7.8	
Mechanical	5.9	
Miscellaneous	.9	14.6
		100.0

Classification of Employees

Classification	Shift			Total
	1st	2d	3d	
Underground - mechanized units:				
Shuttle-car operators	5	5	4	14
Motormen	6	6	4	16
Brakemen	4	4	3	11
Loading-machine men	9	9	7	25
Cutting-machine men	7	7	5	19
Cutting-machine helpers	7	7	5	19
Drillers	9	9	7	25
Timbermen	9	9	7	25
Trackmen	4	4	3	11
Shotfirers	3	3	3	9
Foremen	5	5	4	14
Total	68	68	52	188
Other underground employees:				
Motormen	2	2	5	9
Brakemen	2	2	5	9
Trackmen	8	2	1	11
Timbermen	4	-	-	4
Brattice men	2	1	2	5
Pumpers	1	1	1	3
Pipemen	4	-	-	4
Masons	4	1	2	7
Cagers	1	1	-	2
Cage helpers	2	2	-	4
Wiremen	2	-	-	2
Mechanics	8	3	3	14
Mechanics' helpers	4	-	-	4
Laborers	2	-	-	2
Fire bosses	3	-	-	3
Weigh bosses	-	1	-	1
Total	49	16	19	84
Total underground employees	117	84	71	272

Classification	Shift			Total
	1st	2d	3d	
Surface employees:				
Tipplemen	16	14	-	30
Laborers	4	2	-	6
Blacksmiths	3	-	-	3
Car repairmen	4	-	-	4
General repairmen	3	-	2	5
Hoisting engineers	1	1	1	3
Townmen	2	-	-	2
Clerks	3	-	-	3
Total	36	17	3	56
Supervisory employees:				
Superintendent	1	-	-	1
Mine foreman	1	-	-	1
Assistant mine foremen	-	1	1	2
Safety engineer	1	-	-	1
Master mechanic	1	-	-	1
Shop foreman	1	-	-	1
Weighman	1	-	-	1
Outside foremen	1	1	-	2
Electrician	1	-	-	1
Chemist	1	-	-	1
Retail weighmaster	1	-	-	1
Chief clerk	1	-	-	1
Total	11	2	1	14
Total employees	164	103	75	342

Summary of Mechanized Unit Operation (Based on Four Months' Production)

	Trackless section		Track-mounted section	
	Advance	Retreat	Advance	Retreat
Average unit-shifts per day	7.5	6.5	5.0	6.0
Average tons raw coal per unit-shift, estimated	113.0	117.8	120.3	139.3
Average tons clean coal per unit-shift	100.4	104.7	106.9	123.8
Number of men per unit	7.5	7.0	8.5	8.0
Average tons raw coal per man-shift	15.1	16.8	14.2	17.4
Average tons clean coal per man-shift	13.4	14.9	12.6	15.8

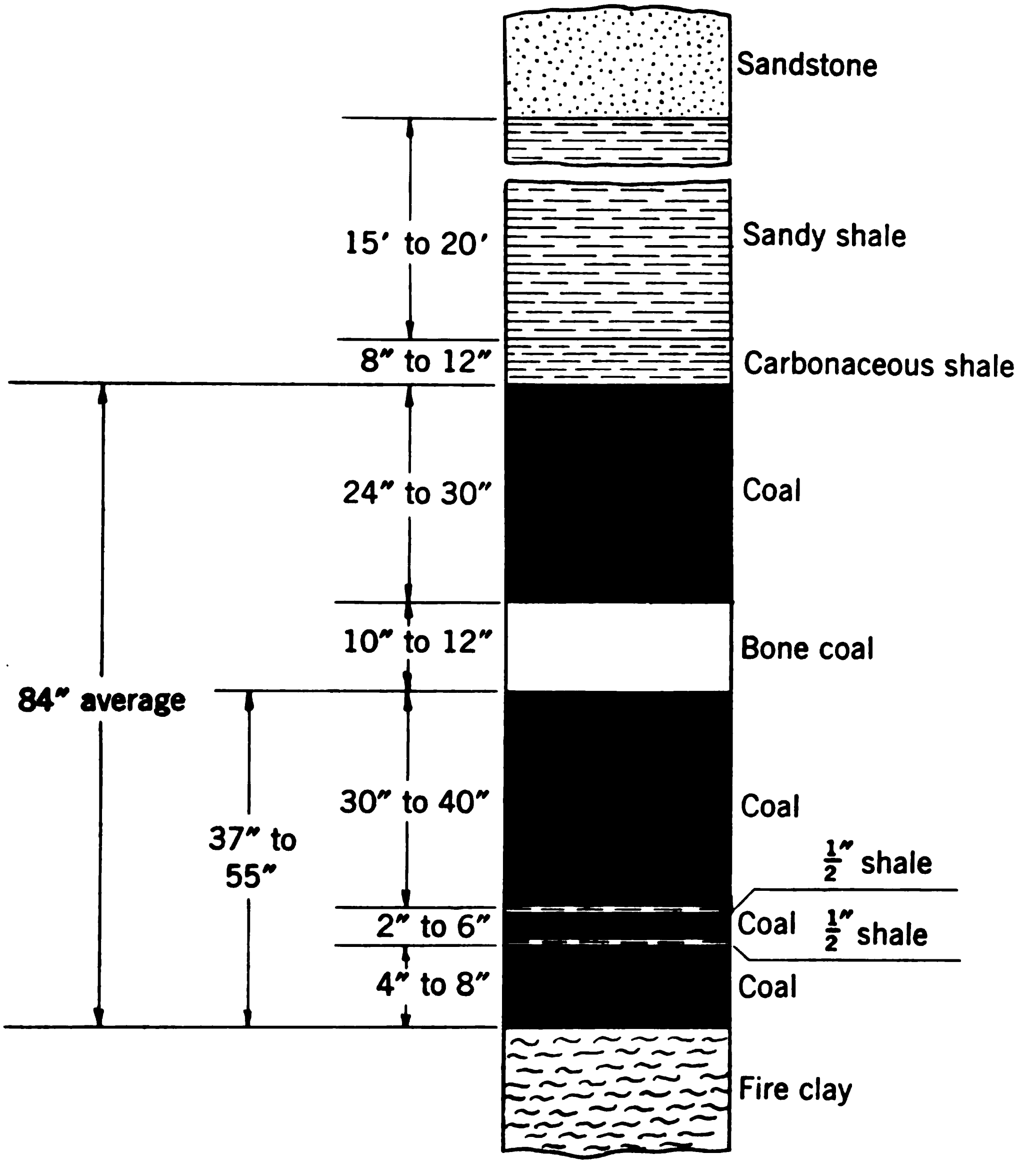

Figure 4. - Section of coal bed at mine 47.

Summary

Percent of mine mechanized	100
Average daily production, raw coal, tons (estimated)	3,400
Average daily production, clean coal, tons	2,725
Average number shifts per day, mechanized units	25
Average production per shift, mechanized units, tons raw coal (estimated)	136
Man-shifts per day, mechanized units	188
Average production per man per shift, mechanized units, tons raw coal (estimated)	18.1
Total man-shifts per day, underground	272
Average production per man per shift, underground, tons raw coal (estimated)	12.5
Total man-shifts per day, surface and underground	342
Average production per man employed per shift, tons raw coal (estimated)	9.9
Average production per man employed per shift, tons clean coal	8.0

Mine 47

Mine 47, which is in western Pennsylvania, is opened by a two-compartment slope, a passageway for men and materials, a vertical coal-hoisting shaft 162 feet deep, an intake air shaft, and a return air shaft. The slope is divided into an upper and a lower compartment. The lower compartment is an intake airway and also is used for transporting supplies and hoisting men. The upper compartment is a manway. A reversible centrifugal fan operated exhausting circulates 300,000 cubic feet of air per minute through the mine.

The thick Freeport bed of coal, which is mined at this operation, averages 84 inches in thickness in this area and contains three partings. (See fig. 4.) A parting of bone coal 10 to 12 inches thick separates the bed into two benches. The upper bench ranges from 24 to 30 inches in thickness, and the lower bench from 37 to 55 inches, with two thin shale partings near the bottom of the bed. The entire thickness of the bed is extracted, but the bone-coal parting is mined separately and is wasted outside of the mine. A stratum of carbonaceous shale 8 to 12 inches thick occurs immediately above the coal bed and provides a good roof in the mine. This shale is overlain by hard, sandy shale and sandstone, which break readily in pillar mining. The floor is fire clay.

Operations at this mine are mechanized completely, and 4,000 tons of coal are produced daily in three shifts. The entire production is used for steam purposes.

Mining Method

Mine 47 was opened about 1919, and for 20 years hand loading was practiced. In 1939, operations were mechanized and a modified form of the room-and-pillar system of mining is now followed. The coal in working places is drilled with electric track-mounted drills and is center-cut in the bone-coal parting by universal cutting machines equipped with 9-foot cutter bars. Permissible explosives, detonated electrically, are used to break the coal, which is loaded into 7-1/2-ton steel mine cars by track-mounted loading machines. Loaded mine cars are gathered by cable-reel locomotives and transported to partings, where they are assembled into trips and hauled to the shaft bottom by trolley locomotives. Track gage is 44 inches.

The mine is developed by multiple main and face entries, which are driven to the property lines. Face entries are turned at right angles to main entries at intervals of 2,000 feet. Butt entries, turned both to the right and left from face entries, are 400 feet apart and are driven 2,000 feet. These butt entries are driven 12 feet wide, in pairs, on 75-foot centers and are connected by crosscuts every 100 feet. Thus, the areas to be mined are divided into panels approximately 475 by 2,000 feet. Rooms on 100-foot centers are turned 90 degrees from the inby butt entry and are developed as the butt entries advance. These rooms are driven 12 feet wide and are 300 feet long. A pillar approximately 100 feet wide separates the rooms from the next inby panel. The sixth room in the panel (fig. 5) is driven through this pillar to provide an escapeway between adjacent panels. The inby end of this room is sealed by a cinder-block stopping equipped with a trap door.

Each panel is ventilated by a separate split of air. Air enters the panel through the inby butt entry and is deflected to the room faces by curtains across the entry. The air passes through the inby crosscuts between the rooms and across the working faces to the outby entry, which is the return airway for the panel. (See fig. 5.)

Development of the panel is complete when the butt entries have been advanced 2,000 feet and the 19 rooms in the panel have been driven to a depth of 300 feet. (See fig. 5.) A completely developed panel comprises a chain pillar, a barrier pillar separating it from the preceding panel, and room pillars that are 88 by 88 feet. Pillars are extracted on retreat from the panel.

Pillar Extraction

Approximately 65 percent of the production at the time of this study was from retreat mining and 35 percent from advance mining. However, 25 percent of the coal in a panel is mined on advance, and 75 percent is recovered on retreat.

Pillar extraction begins as soon as rooms 18 and 19 have been driven through the barrier pillar into the gob of the preceding panel. The inby block of coal between rooms 18 and 19 is extracted by the pocket-and-fender method. (See fig. 6.) A pocket (A, fig. 6) 14 feet wide is turned into the block from room 18 and is driven through the block to room 19. A fender 8 to 10 feet thick separates this pocket from the gob. When the first pocket has advanced five cuts, a second pocket (B, fig. 6) is turned into the block from the crosscut between rooms 18 and 19. This pocket also is 14 feet wide, and an 8- to 10-foot fender is left between it and the gob. Cuts in pockets A and B then are made alternately. Alternate pockets are driven into the block

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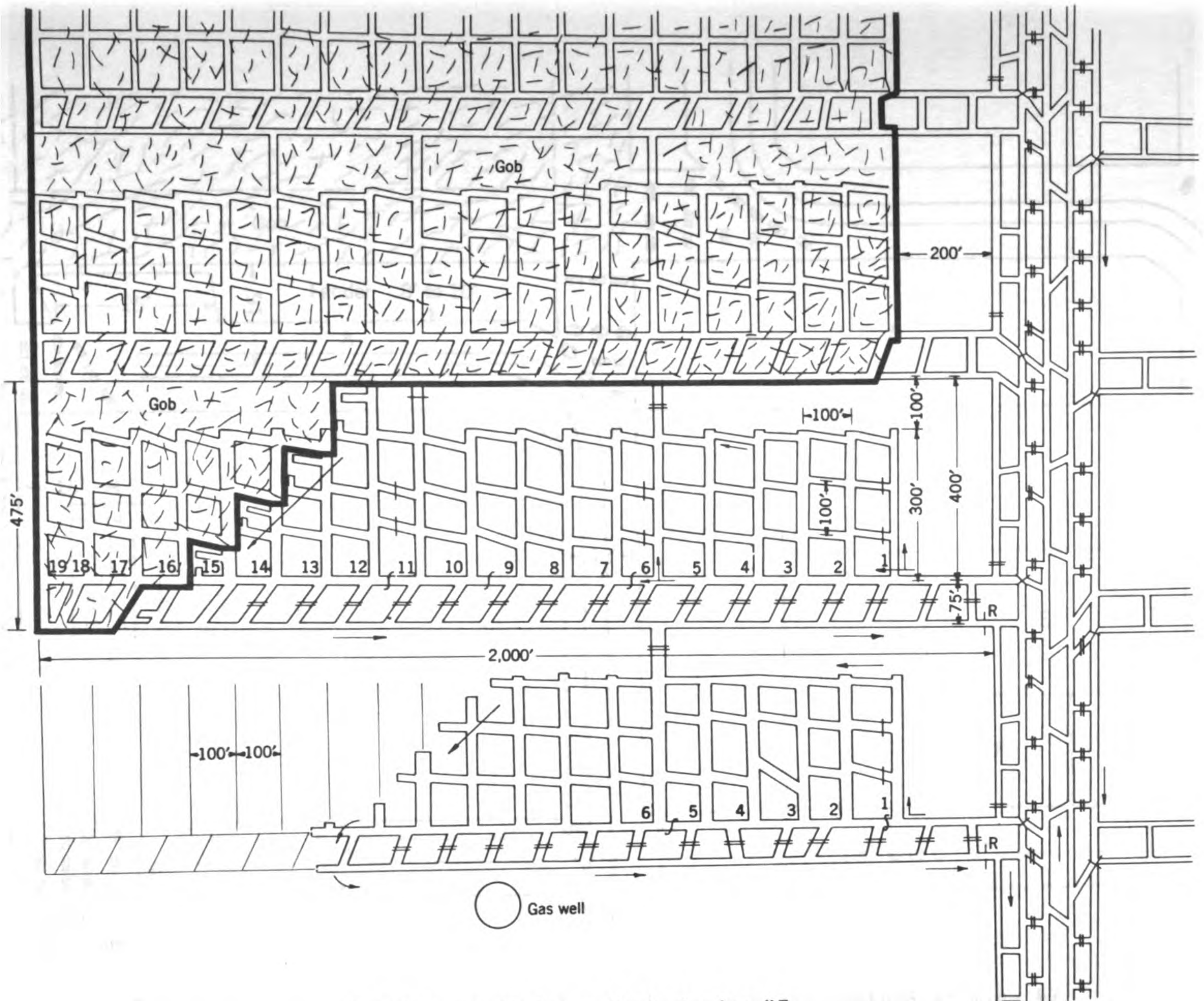

Figure 5. - Mining method at mine 47.

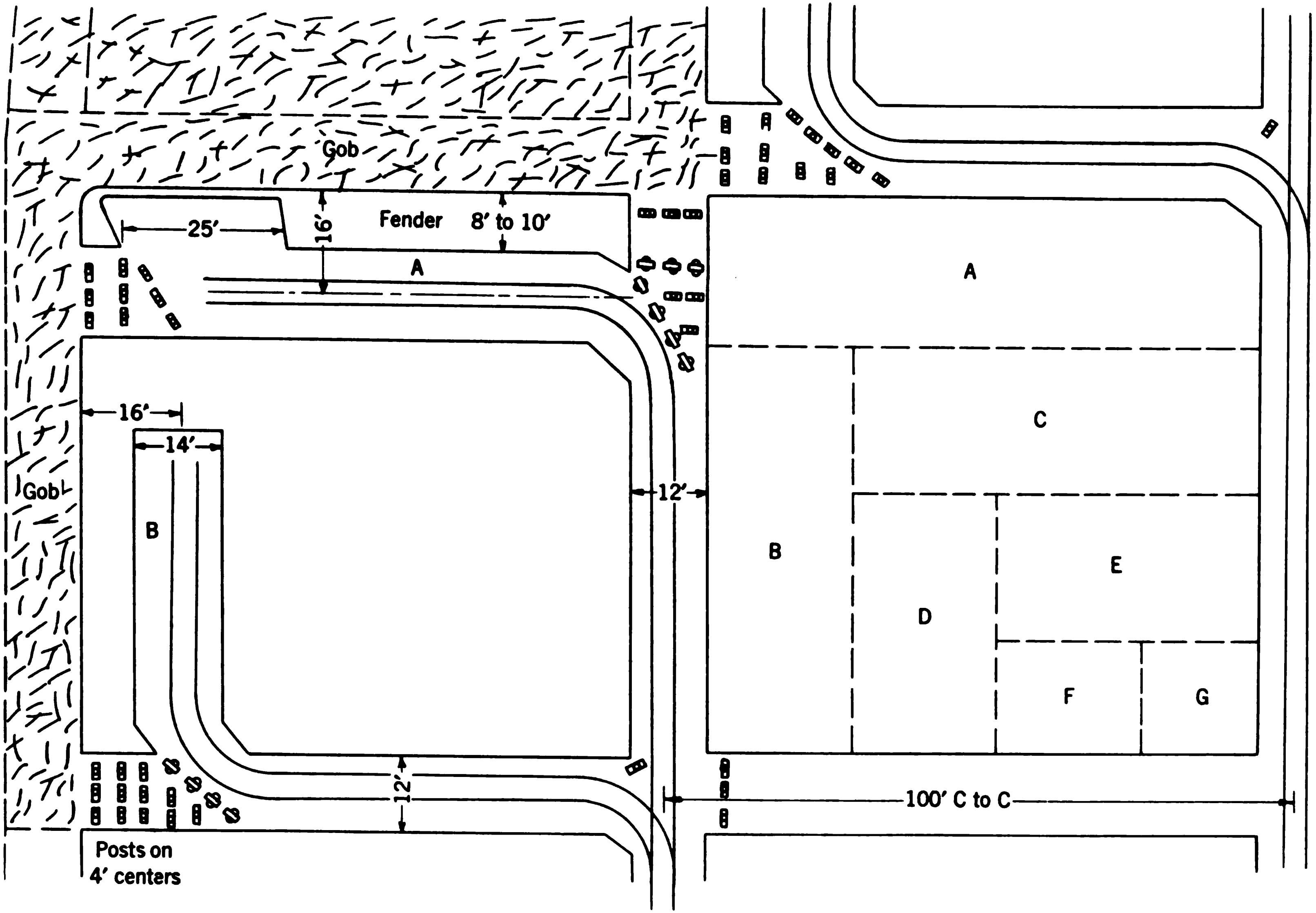

Figure 6. - Pillar extraction by the pocket and fender method at mine 47.

until the pillar has been extracted. Figure 6 shows the order, A to G, of mining crossovers in each block. Room 17 is driven through the barrier pillar at the same time the inby pillar between rooms 18 and 19 is being extracted. All blocks are extracted in the same manner, and operations are timed to establish a pillar line 45 degrees to the butt entries.

Fenders are extracted on retreat from pockets. Side cuts 25 feet long and 9 feet deep are made in the fender. A thin shell of coal 10 to 12 inches thick on the inby side of the fender separates the working place from the gob; this shell is not recovered. Occasionally, where roof conditions permit, longer cuts are made in the fender. Timing of cuts and length of fender cuts are supervised by the foreman in charge of each pillar section.

The main cleavage of the roof rock is parallel to the butt entries, but the roof breaks readily in either the plane of the main cleavage or the secondary cleavage, which is parallel to the rooms. Falls are well-controlled, and the roof rock breaks soon after the fender has been removed. Interference in roof control sometimes occurs in areas of low coal that cannot be mined and in areas adjacent to gas-well pillars. The roof is supported partly by the unmined coal in these areas, and clean breaks in the roof cannot be obtained. However, roof control at this mine is effective, and little coal is lost because of premature falls. The recovery in panels is approximately 93 percent.

One operating unit is employed in each panel. An operating unit comprises 14 men, a track-mounted drill, a track-mounted cutting machine, a track-mounted loading machine, and a cable-reel gathering locomotive. A typical mining cycle for an operating unit follows:

1. Timber.
2. Lay track.
3. Drill.
4. Cut.
5. Load cuttings.
6. Blast.
7. Load coal.
8. Clean-up.

1. Timber. - Timbering in the working place is done by one man. The mine roof generally is good, and usually close timbering is not required. Where it is necessary to use timber sets, crossbars are raised into position with the cutter bar of the cutting machine. The cutter bar is equipped with a special platform for this purpose.

2. Lay track. - Track is advanced to the working face by two men, who also recover it from worked-out places. Switches are placed on steel switch ties, and 40-pound rail on steel mine ties is used in working places.

3. Drill. - The coal is drilled with a track-mounted electric drill using 4-foot and 9-foot augers with double-pointed bits. Three holes are drilled in the upper bench next to the roof, and three holes in the lower bench near the fire-clay floor. A two-man crew operates the drilling machine.

4. Cut. - Track-mounted universal machines are used to center-cut the coal bed. A 10-inch cut is made in the bony coal by inclining the cutter bar slightly in the direction of cut. Water is sprayed on the bits during cutting to allay the dust.

5. Load cuttings. - The cuttings are loaded into 7-1/2-ton mine cars by track-mounted loading machines. These cuttings are high-ash bone coal and are wasted outside of the mine.

6. Blast. - The holes are charged with permissible explosive and detonated electrically. Five sticks of explosive are used in each bottom hole and four sticks in each top hole. The center hole of the bottom bench is fired first, and the other two holes are blasted singly. Top holes are fired in the same order.

7. Load coal. - Track-mounted loading machines load coal into steel mine cars. Approximately five cars of coal are loaded from a pocket cut.

8. Clean-up. - Two men follow the loading machine to clean up the coal and cuttings that the machine is unable to load. When necessary, the clean-up crew is used as an extra timber crew.

The crew on an operating unit is classified as follows:

Driller	1
Assistant driller	1
Cutter	1
Assistant cutter	1
Shotfirer	1
Loading-machine operator	1
Loading-machine helper[1]	1
Motorman	1
Timberman	1
Trackmen	2
Clean-up men	2
Laborer	1
Foreman[2]	1/2
Total	14-1/2

[1] Also performs duties of brakeman.

[2] Foreman supervises two sections.

Studies show that one complete cycle in pillar extraction requires an average of 171 minutes. The average percentage of time spent in each operating phase of the cycle follows:

	Percent
Timber	8.8
Lay track	16.4
Drill	19.3
Cut	14.6
Load cuttings	4.1

		Percent
Blast		11.7
Load coal		17.5
Delays:		
Mechanical	3.5	
Transportation	1.2	
Miscellaneous	2.9	7.6
		100.0

Classification of Employees

Classification	Shift 1st	Shift 2d	Shift 3d	Total
Underground - mechanized units:				
Loading-machine operators	6	6	6	18
Loading-machine helpers	6	6	6	18
Cutting-machine operators	6	6	6	18
Cutting-machine helpers	6	6	6	18
Drill operators	6	6	6	18
Drill helpers	6	6	6	18
Shotfirers	6	6	6	18
Motormen	6	6	6	18
Trackmen	12	12	12	36
Timbermen	12	12	12	36
Clean-up men	12	12	12	36
Foremen	3	3	3	9
Total	87	87	87	261
Other underground employees:				
Motormen	4	4	4	12
Brakemen	4	4	4	12
Trackmen	4	4	4	12
Drainage men	2	2	2	6
Ventilation men	3	1	1	5
Timbermen	1	1	1	3
Clean-up men	8	2	2	12
Wiremen	4	1	1	6
Mechanics	4	4	4	12
Mechanics' helpers	2	2	2	6
Cable splicer	1	-	-	1
Laborer	1	-	-	1
Bottom men	2	1	-	3
Supply men	2	2	-	4
Fire bosses	2	2	2	6
Electrician	1	-	-	1
Shop foremen	1	1	1	3
Assistant mine foremen	1	1	1	3
Total	47	32	29	108
Total underground employees	134	119	116	369

Classification	Shift			Total
	1st	2d	3d	
Surface employees:				
Hoisting engineers	2	2	1	5
Weighmen	1	1	-	2
Dumpers	1	1	-	2
Topmen	1	1	-	2
Bony pickers	2	2	-	4
Lamp men	1	1	1	3
Watchmen	-	1	1	2
Janitor	1	-	-	1
Welders	2	-	-	2
Carpenters	3	-	-	3
Machinist	1	-	-	1
Mechanics	4	-	-	4
Car repairmen	2	-	-	2
Truck drivers	2	-	-	2
Blacksmiths	2	-	-	2
Laborers	19	-	-	19
Yard foreman	1	-	-	1
Tipple foreman	1	-	-	1
Assistant tipple foreman	-	1	-	1
Total	46	10	3	59
Supervisory employees:				
Superintendent	1	-	-	1
Mine foreman	1	-	-	1
Safety engineer	1	-	-	1
Master mechanic	1	-	-	1
Mining engineers	3	-	-	3
Clerks	3	-	-	3
Storeroom clerks	3	-	-	3
Total	13	-	-	13
Total employees	193	129	119	441

Summary

Percent of mine mechanized	100
Average daily production, raw coal, tons (estimated)	4,390
Average daily production, clean coal, tons	3,950
Average number of shifts per day, mechanized units	18
Average production per unit-shift, tons raw coal (estimated)	244
Average production per unit-shift, tons clean coal	220
Man-shifts per day, mechanized units	261
Average production per man per shift, mechanized units, tons raw coal (estimated)	16.8
Average production per man per shift, mechanized units, tons clean coal	15.1
Total man-shifts per day, underground	369
Average production per man per shift, underground, tons raw coal (estimated)	11.9

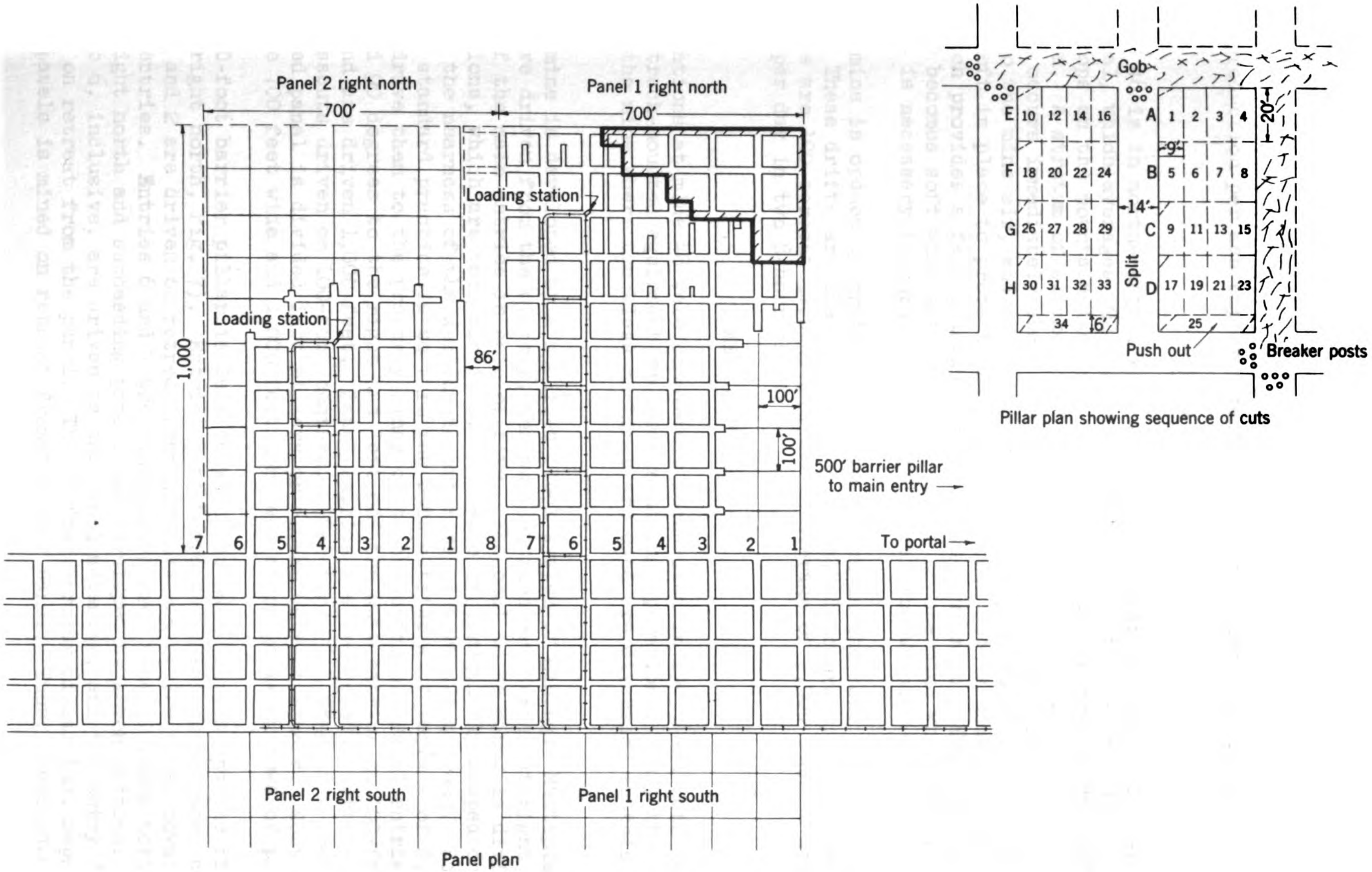

Figure 7. - Mining method at mine 48.

Average production per man per shift, underground, tons clean coal	10.7
Total man-shifts per day, surface and underground	441
Average production per man employed per shift, tons raw coal (estimated)	9.9
Average production per man employed per shift, tons clean coal	9.0

Mine 48

Mine 48 is in north-central West Virginia and operates in the Pittsburgh bed of coal, which averages 102 inches in thickness in this area. The coal bed outcrops on the mountainside and is overlain by an average of 185 feet of overburden. A stratum of slickensided shale ranging from 4 to 24 inches in thickness occurs immediately above the coal. This shale deteriorates when exposed to the mine air, and in some parts of the mine about 12 inches of top coal is left in place to protect the roof. The coal bed is underlain by fire clay, which provides a fair roadway for trackless equipment. However, this fire clay becomes soft when wet, and in sections of the mine where water exists it is necessary to corduroy the shuttle-car roadways.

The mine is opened by drifts that were driven in the coal bed from the outcrop. These drifts are the main haulage roads, air courses, and escapeways. Operations are 100 percent mechanized, and an average of 7,500 tons of coal is produced per day in two 8-hour shifts.

Mining Method

Operations at mine 48 were completely mechanized in 1945, and both trackless and track-mounted equipment are used in mining operations. Only the sections of the mine where trackless machines are used are discussed in this report.

The mine is developed by a modified block system of mining. Multiple main entries are driven from the outcrop, and butt entries are turned at right angles off the main entries in sets of five. The coal to be mined is divided into sections, which are variable in size because of irregularly shaped coal areas and the nearness of the section to outcrops or worked-out areas. However, the standard practice is to turn the butt entries at intervals of 2,000 feet and drive them to the property lines or to the outcrop. Panel entries are turned 90 degrees to the right and left off the butt entries on 100-foot centers and are driven 1,000 feet. Panel entries are connected by right-angle crosscuts driven on 100-foot centers. (See fig. 7.) Thus, the coal in a developed panel is divided into pillars or blocks 86 feet square. Most panels are 700 feet wide and 1,000 feet long and comprise seven rows of pillars.

A 500-foot barrier pillar is left between the main entries and the first panel (1 right north, fig. 7). Entries 3 to 8 are developed on advance, and entries 1 and 2 are driven on retreat from the inby end of the panel toward the butt entries. Entries 6 and 7 are haulageways from panel 1 right north. Panel 2 right north and succeeding panels are developed by seven entries. Entries 1 to 6, inclusive, are driven as the panel advances, and the entry 7 is developed on retreat from the panel. The 86-foot barrier pillar that separates adjacent panels is mined on retreat from the inby panel. Thus, these panels comprise six rows of pillars between entries 1 to 7 and the barrier pillar. (See fig. 7.) The recent practice of splitting the pillar between entries 3 and 4 was established to provide additional working places during development of the panel and to increase the maneuverability of the cable-reel shuttle cars at the loading stations. Entries 4 and 5 are haulageways in panel 2 right north and succeeding panels.

An operating unit in a panel comprises 19 men; one rubber-tired, universal-type cutting machine equipped with a 9-foot cutter bar; one hand-held, electric, auger-type drill; one crawler-mounted loading machine; two 7-ton, cable-reel, shuttle cars; one elevating conveyor; and a car-spotter hoist. This unit develops the panel and also mines the pillars.

Loading stations are located at crosscuts in the outby haulage entry and are advanced every other crosscut as the panel is developed. The track is left in place when a loading station is advanced, because the same station is used on retreat from the panel. Figure 8 shows a typical loading station and track layout. Empty cars are pulled into entry 4 and through crosscut AB into entry 5. The trip then is pushed by the locomotive into crosscut CD and coupled to empty cars at the loading station. The locomotive returns to entry 4 via crosscut BA and couples onto the loaded cars in entry 4. A continuous supply of cars usually is maintained at the loading station, and little time is lost due to car change. The elevating conveyor at the loading station is set at an angle that permits shuttle cars to unload on either side of the conveyor. (See fig. 8.) Shuttle cars approach the conveyor from two directions, but the capacity of the conveyor permits only one car to unload at a time. Water is sprayed on the coal as the shuttle car unloads and as the coal is discharged from the loading boom of the elevating conveyor into 10-ton steel mine cars. One man operates the spotter-hoist, elevating conveyor, and the water sprays.

Pillar Extraction

Pillars comprise about 70 percent of the coal in each panel and are extracted on retreat from the panel. Pillar extraction begins as soon as the panel has been developed by panel entries and crosscuts. In the first panel (1 right north, fig. 7), pillar extraction starts in the inby pillar between panel entries 1 and 2. In succeeding panels pillar extraction begins as soon as the two inby crosscuts have been driven through the barrier pillar separating the panels. A pillar line is established about 30 degrees to the panel entries. Development in the panels is timed so that mining of pillars in an inby panel is started when the pillar line of the preceding panel reaches the last entry of the outby panel. Thus, a continuous pillar line is maintained across two or more panels.

The method of pillar extraction and the sequence of cuts in each pillar are shown in figure 7. The first operation in mining a block is to drive a split 14 feet wide through the block parallel to the panel entry. This split is not "holed through" until the inby block has been completely mined and a roof fall occurs. This practice prevents loose gob from rolling into the working place and also lessens the possibility of the fall extending into the

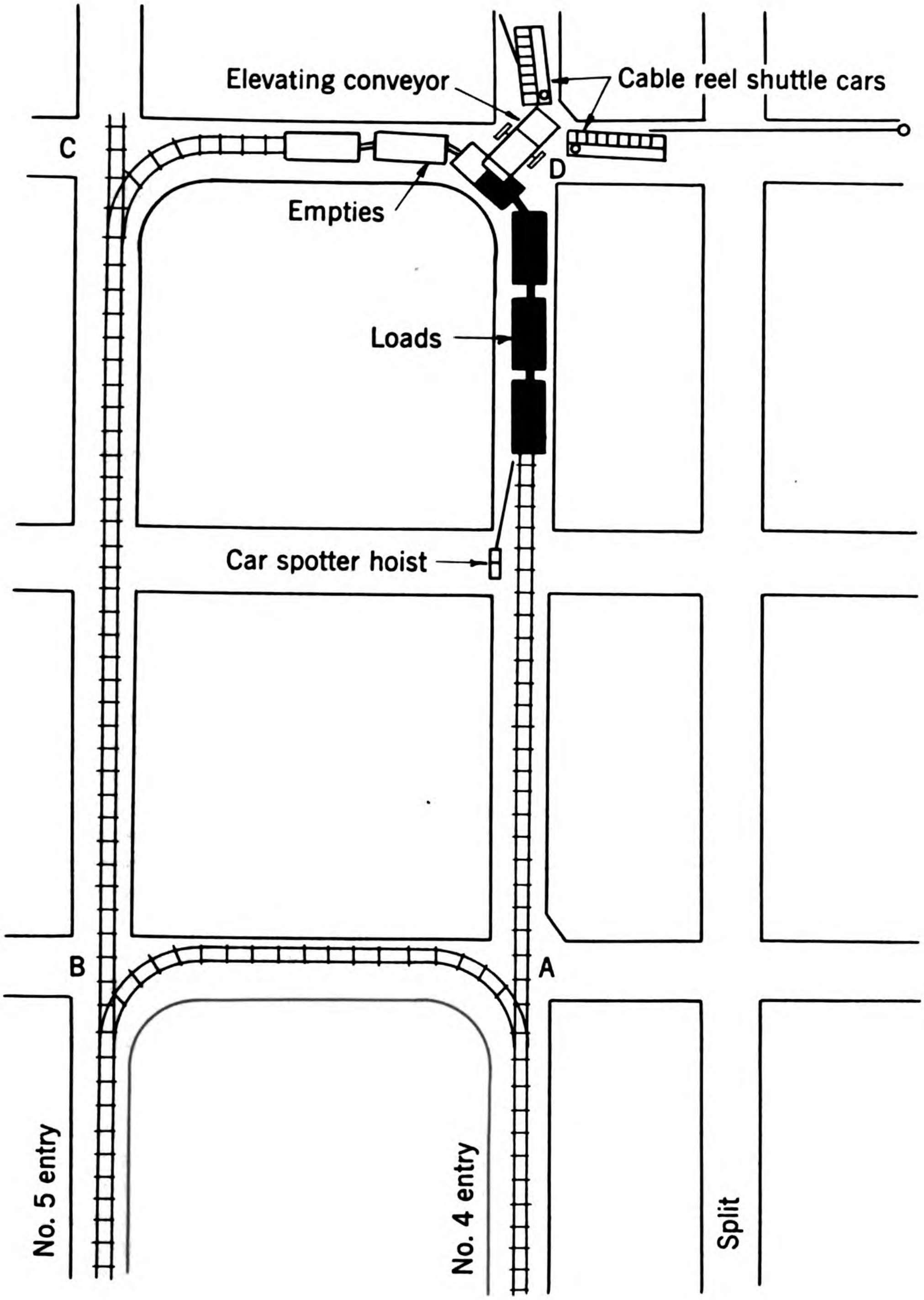

Figure 8. - Loading station and track layout at mine 48.

split. After the split has been completed and the pillar has been divided into two blocks 36 feet wide and 86 feet long, a 20-foot lift is driven across the inby end of the block next to the gob area. (Cuts 1 to 4, fig. 7.) Each block comprises four 20-foot lifts and 6-foot stump, which is called a "push-out." Lifts A and B (fig. 7) are mined in succession, and lifts C and E are mined together. Lifts F and D then are mined together, and G and H are mined in succession. The "push-outs" are recovered, as shown in the cutting sequence in figure 7.

Each lift comprises four 9-foot cuts. A small triangular stump is left on the gob side of the first cut in each lift to keep the loose gob from mixing with the coal and to give additional support to the overhanging roof. The coal is top-cut, and a shear cut is made next to the stump to separate it from the first cut in the lift. When possible, the remaining cuts in the lift are open-ended. However, if the timbers or stump show signs of roof pressure, additional stumps are left along the gob side of the lift. After the coal from the last cut in the lift has been recovered, props and cross bars are removed from the lift. The timber crew then sets five breaker posts - three in the first row and two in the second row - in the split or entry in line with the rib of the next lift. If a roof fall does not occur immediately, the stumps are blasted. The roof rock usually shears near the rib of the solid coal, and the roof pressure does not carry over to the unmined pillar or the breaker posts. The 12 inches of top coal, which is not mined, protects the slickensided shale from deterioration and helps support the overlying strata until the lift has been completed. Normally, a lift is completed in four shifts.

Falls are well-controlled and closely supervised. Each section foreman is required to post his daily progress on a master map in the mine foreman's office. In this way, the foreman on the next shift may know the condition of his section before he enters the mine. At the end of each shift, the mine foreman and superintendent spot-check the section foremen's maps to see that they are up to date and that mining, especially in the pillar sections, is carried on in proper sequence. The mine officials supervise operations closely to be sure that the pillar line is properly maintained.

Recovery of coal in the panels is estimated at approximately 87 percent, and the over-all mine recovery is about 75 percent.

A unit crew in a trackless section of the mine comprises the following men:

Drillers	2
Cutting-machine operator	1
Cutting-machine helper	1
Timbermen (2 crews)	6
Loading-machine operator	1
Loading-machine helper	1
Shuttle-car operators	2
Shotfirer	1
Spillage and brattice men	2
Loading-station operator	1
Foreman	1
Total	19

The cycle of operation follows:

1. Drill.
2. Cut.
3. Timber.
4. Blast.
5. Load coal.

1. Drill. - The drill unit comprises two men and a portable, hand-held, electric drill. Three holes are drilled near the bottom of the coal bed, and a short hole is drilled halfway between the roof and the floor near the tight side. Bottom holes are drilled 8-1/2 feet deep on 6-foot centers. About 1-1/2 minutes are required to drill each hole.

2. Cut. - The coal is top-cut with a rubber-tired, universal-type, cutting machine equipped with a 9-foot cutter bar. A shear cut is made on one rib line in entries and splits and on the gob side in pillars where stumps are left. Approximately 1 foot of top coal is left above the top cut. In pillar mining, 6-inch hitches are cut in one rib for timber crossbars. The cutting crew also sweeps the cuttings away from the face with the cutter bar to expose the bottom blast holes.

3. Timber. - Two timber crews, comprising three men each, work in each operating unit. Two crossbars are set for each cut in each working place after top and shear cuts have been completed. Props are set as required. Crossbars are hitched in the rib on one end and are supported by a post at the other end. The timbermen also set five breaker posts in splits and entries, as shown in Pillar Plan, figure 7. Occasionally the spillage men help the timbermen.

4. Blast. - The coal is blasted with permissible explosive detonated electrically, one hole at a time. Holes are stemmed with bagged rock dust.

5. Load coal. - Crawler-mounted loading machines are used to load the broken coal into 7-ton, cable-reel shuttle cars. Two shuttle cars are employed with each loading machine. Shuttle cars transport the coal to a loading station, where the coal is loaded into 10-ton steel mine cars.

Classification of Employees

Classification	Shift			Total
	1st	2d	3d	
Underground - mechanized units:				
Loading-machine operators	10	10	2	22
Loading-machine helpers	10	10	2	22
Cutting-machine operators	10	10	2	22
Cutting-machine helpers	10	10	2	22
Drillers	10	10	9	29
Shotfirers	10	10	1	21
Shuttle-car operators	9	8	-	17
Loading-station operators	4	4	-	8
Motormen	6	6	2	14

Classification	Shift			Total
	1st	2d	3d	
Underground - mechanized units (con.):				
Brakemen	6	6	2	14
Trackmen	12	12	4	28
Spillage and ventilation men	14	14	2	30
Timbermen	48	48	8	104
Foremen	10	10	2	22
Total	169	168	38	375
Other underground employees:				
Motormen	8	8	4	20
Brakemen	6	6	4	16
Trackmen	13	8	-	21
Timbermen	8	-	-	8
Wiremen	2	-	-	2
Ventilation men	10	-	-	10
Pumpers	2	2	-	4
Rock dusters	-	-	10	10
Pipemen	-	-	3	3
Materials-recovery men	-	-	2	2
Mechanics	10	10	4	24
Mechanics' helpers	5	5	-	10
Mine foreman	1	-	-	1
Assistant mine foremen	2	2	1	5
Other supervisory employees	4	5	1	10
Total	71	46	29	146
Total underground employees	240	214	67	521
Surface employees:				
Slate pickers	10	10	-	20
Weighmen	1	1	-	2
Car droppers	5	5	-	10
Car trimmers	1	1	-	2
Screenmen	1	1	-	2
Lamp men	1	1	1	3
Substation men	2	2	1	5
Sandmen	1	1	-	2
Blacksmiths	1	1	-	2
Welder	1	-	-	1
Bit sharpeners	2	-	-	2
Greasers	3	-	-	3
Supply men	7	-	-	7
Carpenters	4	-	-	4
Laborers	8	8	-	16
Coal inspectors	1	1	-	2
Watchmen	-	-	2	2
Truck drivers	2	2	-	4
Truck mechanic	1	-	-	1
Bulldozer operator	1	-	-	1

Classification	Shift			Total
	1st	2d	3d	
Surface employees (con.):				
Power-shovel operators	1	1	-	2
Yard foremen	1	1	-	2
Tipple foremen	1	1	-	2
Superintendent	1	-	-	1
Other surface supervisory employees	2	2	-	4
Total	59	38	4	101
Supervisory and mine office employees:				
General superintendent	1	-	-	1
Clerks	9	-	-	9
Supply clerks	4	-	-	4
Engineers	6	-	-	6
Timekeeper	1	-	-	1
Janitress	1	-	-	1
Other supervisory employees	5	-	-	5
Total	27	-	-	27
Total employees	326	252	71	649

Summary

Percent of mine mechanized	100
Average daily production, tons	7,500
Mechanized units	10
Mechanized units, shifts per day	22
Average production per unit-shift, tons	341
Man-shifts per day, mechanized units	375
Average production per man per shift, mechanized units, tons	20
Total man-shifts per day, underground	521
Average production per man per shift, underground, tons	14.4
Total man-shifts per day, surface and underground	649
Average production per man employed per shift, tons	11.6

Mine 49

Mine 49 is in the northern West Virginia coal field and operates in the Pittsburgh coal bed, which averages 100 inches in thickness in this area. The coal bed outcrops on the hillsides and is overlain by an average of 275 feet of cover. The thickness of the overburden ranges from a few feet near the outcrop to approximately 385 feet on the hilltops.

A stratum of slickensided shale 2 to 6 feet thick immediately overlies the coal. This shale deteriorates when exposed to the mine air and is supported with great difficulty. For this reason, 6 to 12 inches of top coal is left in place to protect the shale from the mine air. The thickness of top coal depends on the length of time the mined area is to remain open. The strata above the slickensided shale comprise sandy shale and sandstone.

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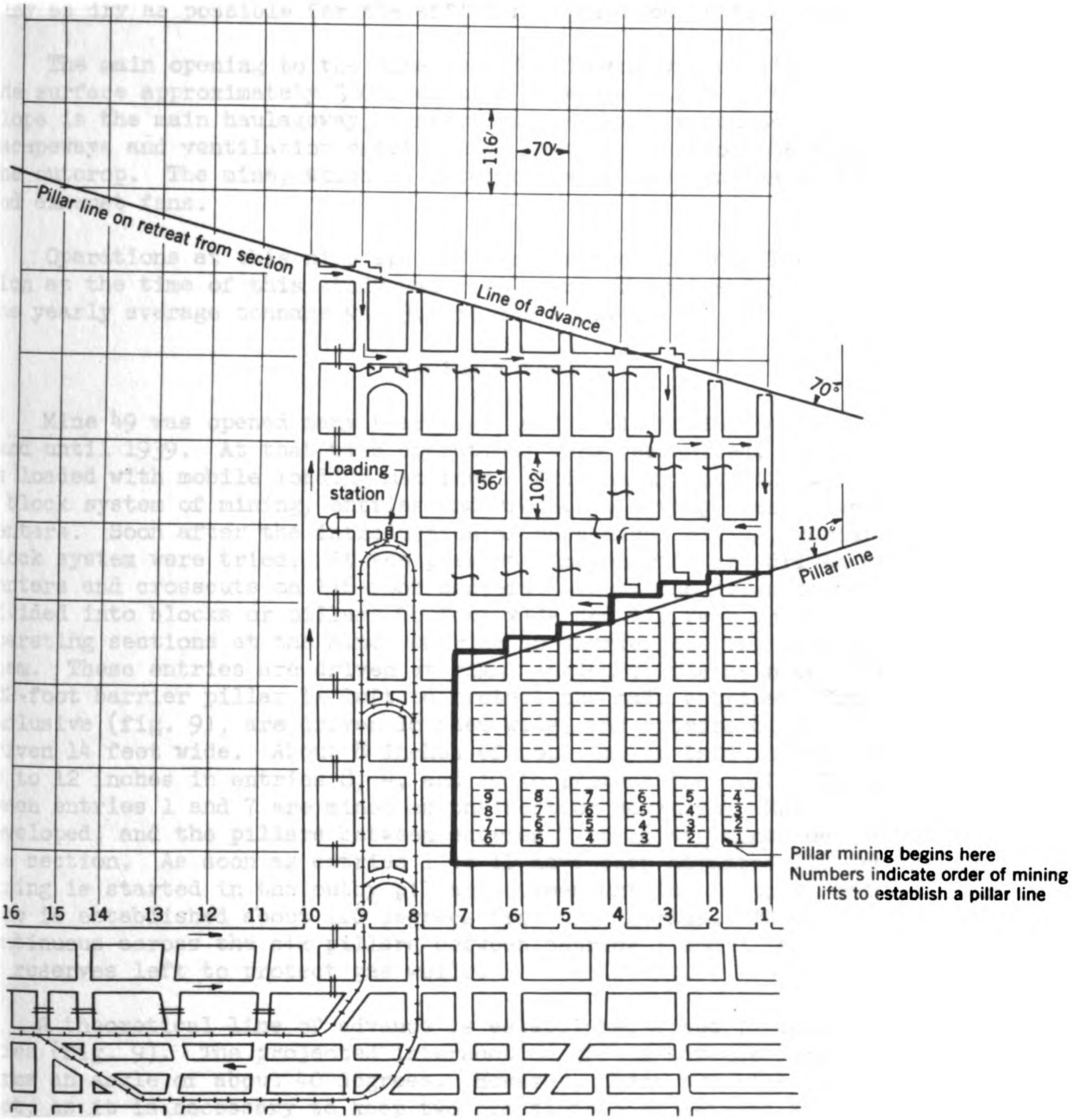

Figure 9. - Mining method at mine 49.

The coal bed is underlain by 18 inches of fire clay, which becomes soft when wet. Sumps, 8 feet in diameter and 3 feet deep, are excavated along the shuttle car roadways to drain the water from the bottom and keep the fire clay as dry as possible for the efficient operation of trackless equipment.

The main opening to the mine is a double-entry rock slope driven from the surface approximately 300 feet on a 7-degree pitch to the coal bed. This slope is the main haulageway, manway, and return air course. A number of escapeways and ventilation entries have been driven from the mine workings to the outcrop. The mine, which is rated nongassy, is ventilated by both blowing and exhaust fans.

Operations at this mine are 100 percent mechanized. The average production at the time of this study was 2,730 tons of coal a day in three shifts. The yearly average tonnage was 3,275 tons a day.

Mining Method

Mine 49 was opened many years ago, and coal was loaded into mine cars by hand until 1939. At that time operations were mechanized, and at present coal is loaded with mobile loading machines. Originally the mine was developed by a block system of mining, entries and crosscuts having been driven on 90-foot centers. Soon after the introduction of mechanical mining, variations of the block system were tried. At the present time entries are driven on 70-foot centers and crosscuts on 116-foot centers. Thus, the areas to be mined are divided into blocks or pillars 56 feet wide and 102 feet long (see fig. 9). Operating sections at the mine comprise 16 entries and the pillars between them. These entries are driven at right angles to the main entries, and a 102-foot barrier pillar is left to protect the main entries. Entries 1 to 7, inclusive (fig. 9), are driven 16 feet wide, and entries 8, 9, and 10 are driven 14 feet wide. About 8 inches of top coal is left in entries 1 to 7 and 10 to 12 inches in entries 8, 9, and 10 to protect the roof. The pillars between entries 1 and 7 are mined as the section advances. Entries 11 to 16 are developed, and the pillars between entries 7 to 16 are mined on retreat from the section. As soon as entries 1 to 10 have been advanced 175 feet, pillar mining is started in the outby pillar between entries 1 and 2, and a pillar line is established about 110 degrees from the entries. This pillar line is continuous across the six pillars between entries 1 and 7, and is broken only by reserves left to protect gas wells.

A theoretical line of advance is established about 70 degrees to the entries (fig. 9). The projected intersection of the advance line and pillar line forms an angle of about 40 degrees. However, these two lines actually do not meet, as it is necessary to keep two crosscuts open between the pillar line and the advance line to maintain proper ventilation in the working places.

Entries 8 and 9 are haulage roads for the entire section and are equipped with track for movement of mine cars to and from the loading stations. Shuttle-car discharge stations are established in every other crosscut between entries 8 and 9. Track and switches are left in place as the loading station is advanced, because the same stations are used on retreat from the section.

The depth of sections is limited by outcrops and nearness to abandoned workings and reserve areas. This mine has been in operation for many years, and the present workings are adjacent to mined-out areas. After entries 1 to 10, inclusive, have been driven to the inby end of the section, entries 11 to 16, inclusive, are turned from crosscuts and developed toward the main entries as the section retreats. Pillar extraction between entries 7 and 16 begins at the inby pillar between entries 7 and 8, and a new pillar line is established as shown in figure 9. This pillar line is 70 degrees from the entry course and 40 degrees from the pillar line, which was established on advance. Pillars comprise about 70 percent of the coal in a section, and approximately 30 percent of the coal in a section is mined from entries and crosscuts.

Pillar Extraction

Each pillar or block comprises four lifts and a stump, as shown in figure 10. The lifts comprise seven 8-foot cuts and the stumps, four 8-foot cuts. Each lift is 21 feet wide and 56 feet long. The first cut in a lift is made from the entry inby the pillar. A triangular stump is left on the gob side of the first cut to help support the roof rock. The coal is top-cut and sheared between the center line of the lift and the gob side of the place. About 6 inches of top coal is left in place to protect the roof. The second, fourth, and sixth cuts in each lift are open-ended, and a 3-foot triangular fender is left on the gob side of cuts 1, 3, 5, and 7 in each lift.

After the last cut has been made in a lift, blast holes are drilled through the top of the fenders to the roof rock. The timber supports in cuts 6 and 7 are then recovered with a post-pulling machine, and the fender in cut 7 is blasted. Usually, the top coal and part of the shale roof fall in the inby end of the lift after the first fender is blasted. The same procedure is followed in removing the other timbers and fenders in the lift. A major roof fall occurs immediately after the timber supports have been recovered and the last fender has been blasted. Occasionally the major fall occurs when the fender in the third cut is blasted.

Falls along the pillar line break to the surface, thus relieving the weight of the unsupported roof on the solid coal.

The section foreman is responsible for maintaining the pillar line and for keeping the lifts the proper width. If one of the cuts is made wider than the lift, the roof fall will carry over into the next lift and create a difficult timbering problem when the coal is mined from that lift. The section foreman also is required to keep entry development at least two crosscuts in advance of pillar extraction in order to provide adequate ventilation in all working places

Approximately 85 percent of the coal in a section is recovered. Occasionally a premature fall closes a lift before all of the coal has been mined. In such cases the coal is recovered from the next lift.

A mechanized unit in a pillar section comprises 19 men, one crawler-mounted loading machine, one rubber-tired universal-type cutting machine, one portable electric drill, two cable-reel shuttle cars, one elevating car-loading conveyor, a car-spotter hoist, and a post-pulling machine. The unit crew is classified as follows:

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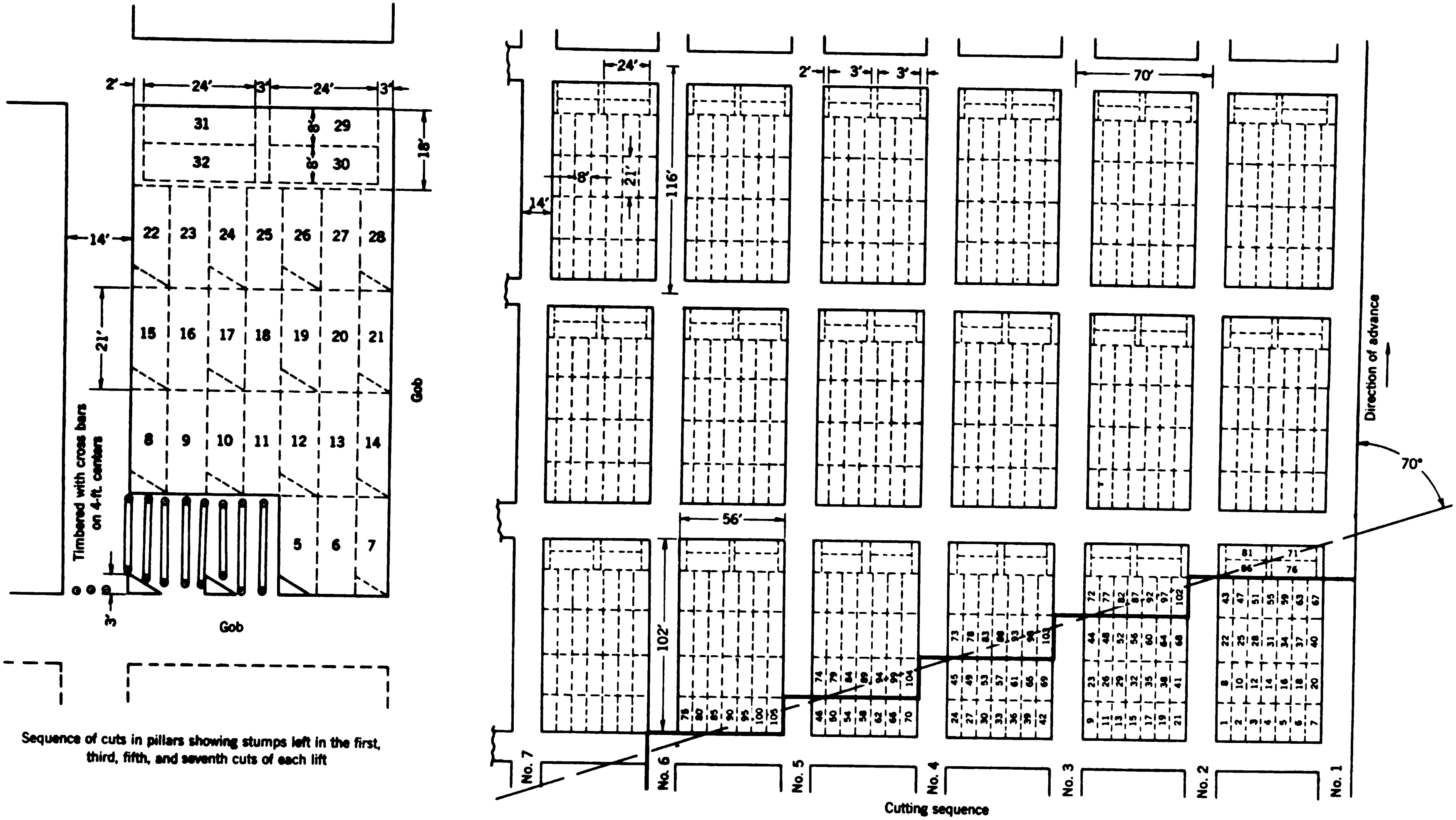


Sequence of cuts in pillars showing stumps left in the first, third, fifth, and seventh cuts of each lift

Figure 10. - Pillar extraction at mine 49.

Drillers	2
Loading-machine operator	1
Loading-machine helper	1
Cutting-machine operator	1
Cutting-machine helper	1
Shuttle-car operators	2
Timbermen (2 crews of 3 each)	6
Shotfirer	1
Clean-up man	1
Duster	1
Loading-station operator	1
Foreman	1
Total	19

A typical cycle of operation in a pillar section of this mine is as follows:

1. Timber.
2. Cut.
3. Dust.
4. Drill.
5. Blast.
6. Clean-up.
7. Load coal.

1. Timber. - Two crews of three men each set crossbars and props to support the roof. After a fall of coal is loaded, the timbermen set two crossbars supported by posts in the working place. Crossbars are set on 4-foot centers, and posts are set along the break line to prevent roof falls from extending into the entries and crosscuts. The timber crew also recovers crossbars and props after mining has been completed in each lift.

2. Cut. - An 8-foot top cut and a center shear cut are made in the coal with a rubber-tired universal-type cutting machine equipped with a 9-foot cutter bar. The top cut is about 6 inches below the top of the coal bed. Water is sprayed on the cutter bar to allay the dust. Two men comprise the cutting-machine crew.

3. Dust. The cuttings from the top and shear cuts are hand-shoveled away from the face to provide working space for the drilling crew. One man is assigned to the work.

4. Drill. - Three holes are drilled near the bottom of the coal bed, two on the solid side and one on the gob side of the shear cut. These holes are drilled with electric auger-type drills mounted on trucks. The drill crew, which comprises two men, also drills holes in the fenders after the coal has been mined from the lift and before the fenders are blasted and timbers removed.

5. Blast. - Coal is blasted with permissible explosive, which is detonated electrically. The holes are fired singly.

6. Clean-up. - Spillage from the previous cut is hand-shoveled to the center of the working place, where it can be loaded by the loading machine. Occasionally, loose roof rock falls on the coal in the fresh cut, and it is necessary for the clean-up man to remove this rock before the coal is loaded.

7. Load coal. - Crawler-mounted loading machines are used to load the fallen coal into 7-1/2-ton shuttle cars, which transport the coal to loading stations. The shuttle cars unload onto an elevating conveyor that discharges the coal into 2.85-ton-capacity steel mine cars. Some of the cars are equipped with wood side boards to enable them to carry 3.5 tons of coal.

Classification of Employees

Classification	Shift[1]			
	1st	2d	3d	Total
Underground - mechanized units:				
Loading-machine operators	3	3	3	9
Loading-machine helpers	3	3	3	9
Cutting-machine operators	3	3	3	9
Cutting-machine helpers	3	3	3	9
Drillers	3	3	3	9
Shotfirers	3	3	3	9
Shuttle-car operators	6	6	6	18
Timbermen	18	18	18	54
Loading-station operators	3	3	3	9
Dusters	3	3	3	9
Clean-up men	3	3	3	9
Foremen	3	3	3	9
Total	54	54	54	162
Other underground employees:				
Motormen	4	4	3	11
Brakemen	4	4	3	11
Trackmen	2	2	-	4
Mechanics	2	2	2	6
Dispatchers	1	1	-	2
Laborers	8	2	3	13
Brattice man	1	-	-	1
Pumpers	3	2	1	6
Wiremen	3	-	-	3
Ditchmen	2	-	-	2
Supply men	-	2	1	3
Bottom men	1	1	-	2
Mine foremen	1	1	1	3
Construction foreman	1	-	-	1
Total	33	21	14	68
Total underground employees	87	75	68	230
Surface employees:				
Tipplemen	17	17	-	34
Hoisting engineers	1	1	-	2

See footnote at end of table on following page.

Classification	Shift[1]			
	1st	2d	3d	Total
Surface employees (con.):				
Trip riders	1	1	-	2
Sand drier	1	-	-	1
Truck driver	1	-	-	1
Lamp men	1	1	-	2
Car repairmen	4	-	-	4
Tipple mechanics	-	1	2	3
Carpenter	1	-	-	1
Mechanics	3	2	2	7
Total	30	23	4	57
Supervisory employees:				
Superintendent	1	-	-	1
Office clerks	3	-	-	3
Supply clerks	2	-	-	2
Maintenance foreman	1	-	-	1
Tipple foremen	1	1	-	2
Total	8	1	-	9
Total employees	125	99	72	296

[1] 1st shift: 7:00 a.m. to 3:00 p.m.
2d shift: 3:00 p.m. to 11:00 p.m.
3d shift: 11:00 p.m. to 7:00 a.m.

Summary

Percent of mine mechanized	100
Average daily production, tons	2,730
Average number of shift per day, mechanized units	9
Average production per mechanized unit-shift, tons	303.3
Man-shifts per day, mechanized units	162
Average production per man per shift, mechanized units, tons	16.85
Total man-shifts per day, underground	230
Average production per man per shift, underground, tons	11.86
Total man-shifts, surface and underground	296
Average production per man employed per shift, tons	9.2

Mine 50

Mine 50, situated in central Pennsylvania, operates in the Lower Freeport coal bed. This bed averages 42 inches in thickness in this area and is overlain by a stratum of carbonaceous shale, locally termed "black slate," about 5 feet thick. The main roof rock immediately above this "black slate" is shale. A stratum of fire clay approximately 21 inches thick underlies the coal bed.

The mine is opened by two drifts and a vertical intake air shaft about 1 mile inby the drift portals. One of the drifts is the main haulageway and intake airway, and the other drift is the main return airway for the mine. A fan, operated exhausting, is near the return air drift and circulates about

70,000 cubic feet of air per minute through the mine at a 3-inch water-gage pressure.

Operations at this mine are completely mechanized, and approximately 1,800 tons of coal are produced a day in two shifts.

Mining Method

Mine 50 was opened in 1917, and coal was loaded by hand for about 20 years. In 1940, all mining operations were mechanized and crawler-mounted loading machines and shuttle cars were installed. Annual production has averaged about 479,000 tons a year during the last 5 years.

The mine is developed by multiple main, face, and butt entries, which comprise five parallel entries on 50-foot centers. The center entry is always the haulageway and intake airway and is driven 12 feet wide. The roof is brushed to provide 5-1/2 feet clearance above the rail. The other four entries are airways and are driven 12 to 24 feet wide, depending on roof conditions. These air courses are driven wide in order that maximum tonnage may be produced during development and to provide ample space for the flow of air through the mine.

Face entries are turned to the left off the main entries at intervals of 1,700 feet and are advanced to the property lines. Butt entries are turned at right angles to the face entries at intervals of 280 feet and are driven 1,600 feet. The panels of coal between butt entries are mined by the room-and-pillar method, and the pillars are extracted. (See fig. 11.)

Two mechanized units are used in each face-entry section. These two units develop the face and butt entries and mine the coal from the rooms and pillars in the panels. A mechanized unit comprises a crawler-mounted loading machine, a shortwall cutting machine with crawler-mounted truck, a portable electric auger drill, two 2-ton battery-operated shuttle cars, one loading elevator, and one car spotter-hoist. At the time of this study, mining was conducted in three face-entry sections with six mechanized units operating two shifts a day. One mechanized unit operated three shifts a day.

One of the units (called "A" in this report) in a face-entry section develops the face entries and turns the butt entries. When the face entries have been advanced 560 feet from the main entries by unit A, a set of butt entries is turned, and a second mechanized unit (called "B" in this report) is placed in these butt entries to complete the development of the panel and mine the coal from the rooms and pillars. A 100-foot barrier pillar protects the main entries. Unit A advances the face entries and turns butt entries at intervals of 280 feet. Unit B develops and mines the coal from the panels beginning at second right butt entry (fig. 11), assuming the first right to be worked out. As soon as the face entries have been driven 1,000 feet beyond the second right butt entry, development of the face entries is stopped. The crew and equipment (unit A) then begins the development of butt entries (third right, fig. 11) for the next panel, while unit B mines the coal in rooms and pillars in the preceding panel (second right, fig. 11). After all the coal

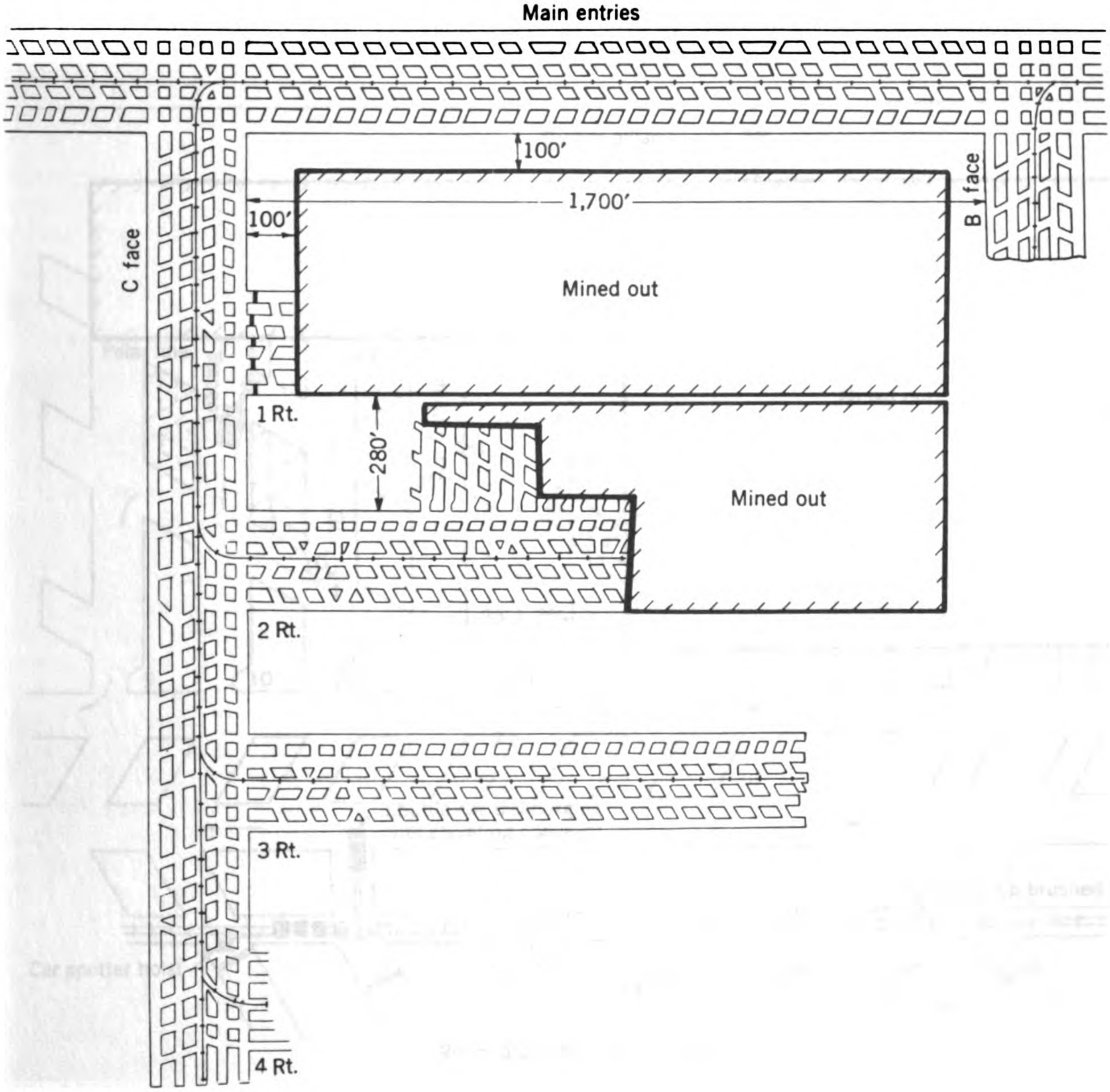
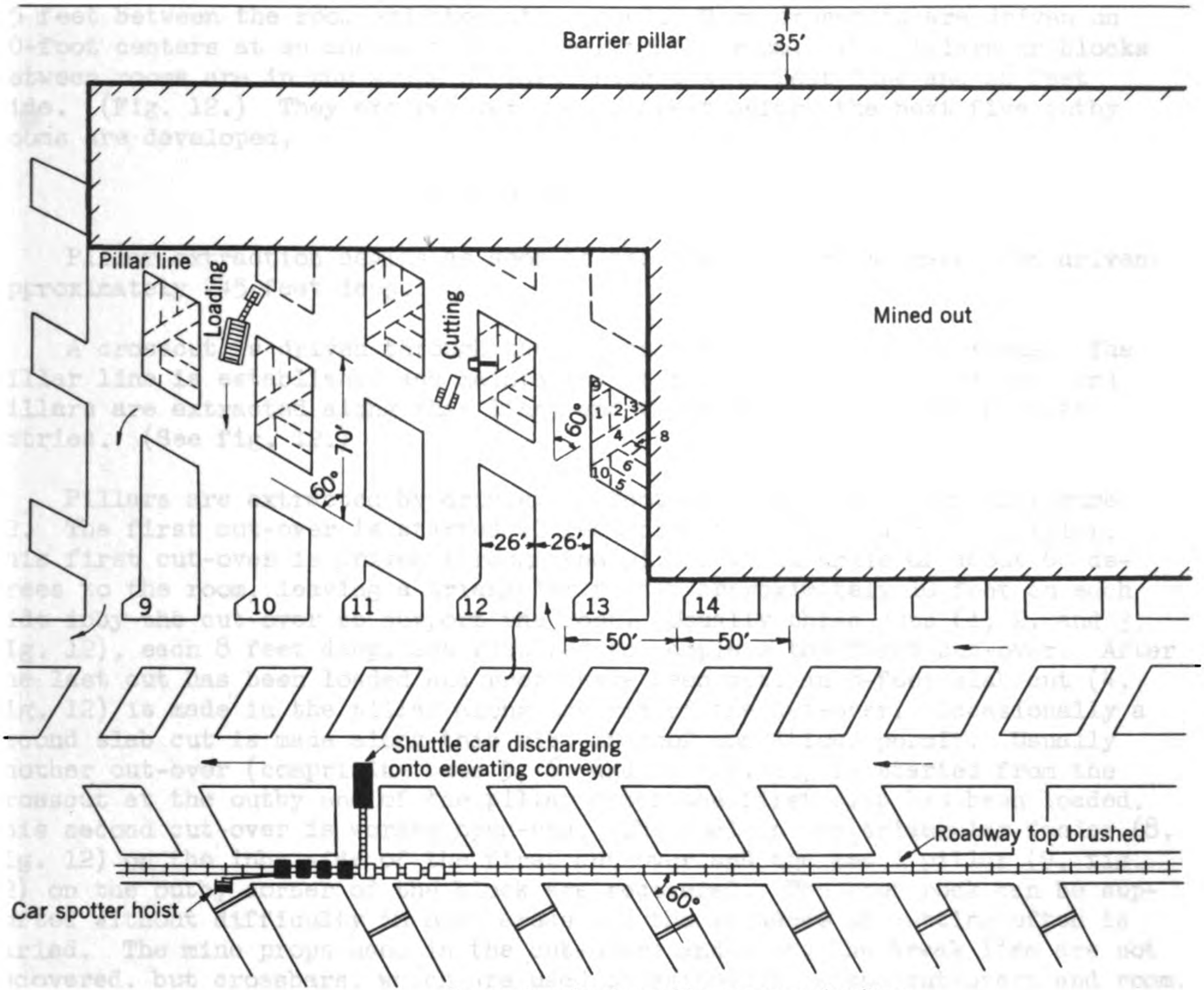


Figure 11. - Mining method at mine 50.



Room plan showing cutting sequence in pillars

Figure 12. - Pillar extraction at mine 50.

has been recovered in the second right panel by unit B, unit A returns to develop the face entries, and unit B replaces unit A in the third right panel.

Panels are 1,500 feet long and about 280 feet wide, and extraction in rooms begins at the face of the butt entries. Five rooms 24 feet wide on 50-foot centers are turned at right angles from the outby butt entry and are driven to a depth of 245 feet, which leaves a barrier pillar of approximately 35 feet between the room and the outby panel. Room crosscuts are driven on 70-foot centers at an angle of 60 degrees to the room. The pillars or blocks between rooms are in the shape of parallelograms 50 feet long and 26 feet wide. (Fig. 12.) They are recovered on retreat before the next five outby rooms are developed.

Pillar Extraction

Pillar extraction begins as soon as the five inby rooms have been driven approximately 245 feet deep.

A crosscut is driven through the pillars at the face of the rooms. The pillar line is established and maintained at right angles to the rooms, and pillars are extracted along this line, and the retreat is toward the butt entries. (See fig. 12.)

Pillars are extracted by driving 22-foot cut-overs, as shown in figure 12. The first cut-over is started 10 feet from the inby end of the pillar. This first cut-over is driven through the pillar at an angle of about 60 degrees to the room, leaving a triangular fender approximately 10 feet on each side inby the cut-over to support the roof. Usually three cuts (1, 2, and 3, fig. 12), each 8 feet deep, are required to complete the first cut-over. After the last cut has been loaded and props have been set, an 8-foot slab cut (4, fig. 12) is made in the pillar along the rib of the cut-over. Occasionally a second slab cut is made along this rib, if roof conditions permit. Usually another cut-over (comprising cuts 5, 6, and 7, fig. 12) is started from the crosscut at the outby end of the pillar after the first slab has been loaded. This second cut-over is worked open-end. The coal in the triangular fender (8, fig. 12) on the inby side of the first cut-over and the small pillar (9, fig. 12) on the outby corner of the block are recovered. The roof rock can be supported without difficulty in most areas and the sequence of cutting often is varied. The mine props used in the cut-overs and along the break line are not recovered, but crossbars, which are used occasionally in the cut-overs and room, are recovered when possible. At times the weight of the roof becomes excessive, and it is necessary to abandon a cut-over before it is completed. When this occurs, the coal that remains in the pillar is recovered from the other cut-over. The roof rock is strong, and it is often necessary to weaken the supports to break the roof along the pillar line. Falls are controlled, and little coal is lost as a result of squeezes or premature falls of roof rock.

Chain pillars are recovered in the same manner that room pillars are extracted. These pillars are recovered by the unit that develops the rooms and extracts room pillars. The first chain pillars are mined after the coal from the second 5-room unit is extracted, and these chain pillars are recovered as far as the outby room of the first 5-room unit. Thus, chain-pillar extraction is always one step behind room development and room-pillar mining.

In 1 year one mechanized unit can develop and retreat a panel approximately 500 by 1,500 feet. Approximately 88 percent of the coal in the panel is recovered. A typical cycle of operation follows:

1. Cut and timber.
2. Drill.
3. Blast.
4. Load coal.

1. Cut and timber. - The coal is undercut with shortwall machines equipped with 8-foot cutter bars. Pillar cuts are 22 feet wide and produce about 20 tons of coal per cut. Occasionally it is necessary to cut in the floor rock to attain enough clearance for the loading machines and shuttle cars. When this is done, the cuttings are loaded separately and wasted outside of the mine. The cutting machine is transported on a crawler-mounted truck. Two men comprise the cutting crew. These men also timber the working places.

2. Drill. - The coal is drilled with an electric, hand-held drill equipped with a double, balanced-torque bit. The auger is 8 feet long, and the cuttings are conveyed through the hollow outer casing to an outlet near the motor. Holes are drilled in less than 1 minute each. Three holes are drilled in a 22-foot face. Two of the holes are in the upper corners of the face, and a third hole is placed in the center. All of the holes are angled upward, so that the inby end of the hole is near the roof. Additional timbers are set by the driller and the shotfirer.

3. Blast. - The shotfirer and the driller work together. As soon as the driller completes his work, the shotfirer prepares the coal for blasting. Permissible explosives detonated electrically are used in all parts of the mine. Four sticks of explosives are used in each of the holes. The middle hole is fired first, and the corner holes are fired singly.

4. Load coal. - Crawler-mounted loading machines load coal into 2-ton-capacity, battery-operated shuttle cars. Two shuttle cars are used with each loading machine. The loading crew comprises an operator and a helper who hand-shovels the coal that the machine cannot reach and assists in tramming the loading machine from place to place. A unit crew comprises the following men:

Cutting-machine operator	1
Cutting-machine helper	1
Driller	1
Shotfirer	1
Loading-machine operator	1
Loading-machine helper	1
Shuttle-car operators	2
Loading-boom operator	1
Foreman	1
Total	10

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Classification of Employees

Classification	Shift			Total
	1st	2d	3d	
Underground - mechanized units:				
Cutting-machine operators	6	6	1	13
Cutting-machine helpers	6	6	1	13
Drillers	6	6	1	13
Shotfirers	6	6	1	13
Loading-machine operators	6	6	1	13
Loading-machine helpers	6	6	1	13
Shuttle-car operators	12	12	2	26
Loading-head operators	6	6	1	13
Foremen	6	6	1	13
Total	60	60	10	130
Other underground employees:				
Motormen	9	9	3	21
Mechanics	6	4	2	12
Mechanics' helpers	2	2	2	6
Wiremen	2	-	-	2
Pumpers	2	2	2	6
Pipemen	4	-	-	4
Trackmen	4	4	-	8
Timbermen	4	4	-	8
Brattice men	2	2	-	4
Electricians	1	1	-	2
Supply men	-	-	4	4
Rockmen	-	-	6	6
Mine foreman	1	-	-	1
Assistant foremen	-	1	1	2
Total	37	29	20	86
Total underground employees	97	89	30	216
Surface employees:				
Superintendent	1	-	-	1
Clerks	1	1	-	2
Engineers	2	-	-	2
Tipplemen	19	19	-	38
Sand dryer	1	-	-	1
Car repairmen	3	-	-	3
Truck drivers	1	1	-	2
Blacksmiths	1	1	-	2
Yard foremen	1	1	-	2
Total	30	23	-	53
Total employees	127	112	30	269

Summary

Percent of mine mechanized	100
Average daily production, tons	1,800
Number of mechanized units	6

Average number shifts per day, mechanized units	13
Average production per unit per shift, tons	138.4
Man-shifts per day, mechanized units	130
Average production per man per shift, mechanized units, tons	13.8
Total man-shifts per day, underground	216
Average production per man per shift, underground, tons	8.3
Total man-shifts per day, surface and underground	269
Average production per man employed per shift, tons	6.7
Average tons of coal per mine prop	3.5

Mine 51

Mine 51 is in central Pennsylvania and operates in the Lower Kittanning coal bed, which averages 28 inches in thickness in this area. The coal bed is overlain by a stratum of hard shale, which provides a good roof, and the floor rock comprises 18 inches of hard, smooth shale underlain by fire clay. The shale floor rock is very irregular and contains numerous rolls, which protrude into the coal bed. In most places the rolls are small and do not hamper the movement of men and equipment, but occasionally these rolls are large enough to restrict passage of men and materials. When this condition occurs, pneumatic pick hammers are used to cut through the rolls to provide the necessary clearance for mining operations.

This mine is opened by a vertical hoisting shaft 507 feet deep and a vertical air shaft. Approximately 50,000 cubic feet of air per minute is circulated through the mine by a blowing fan. This mine is rated nongassy.

Approximately 70 percent of the coal is hand-loaded onto conveyors; the rest is hand-loaded into mine cars. The average daily production is about 500 tons. Mechanized sections operate three shifts a day and the hand-loading sections one shift a day.

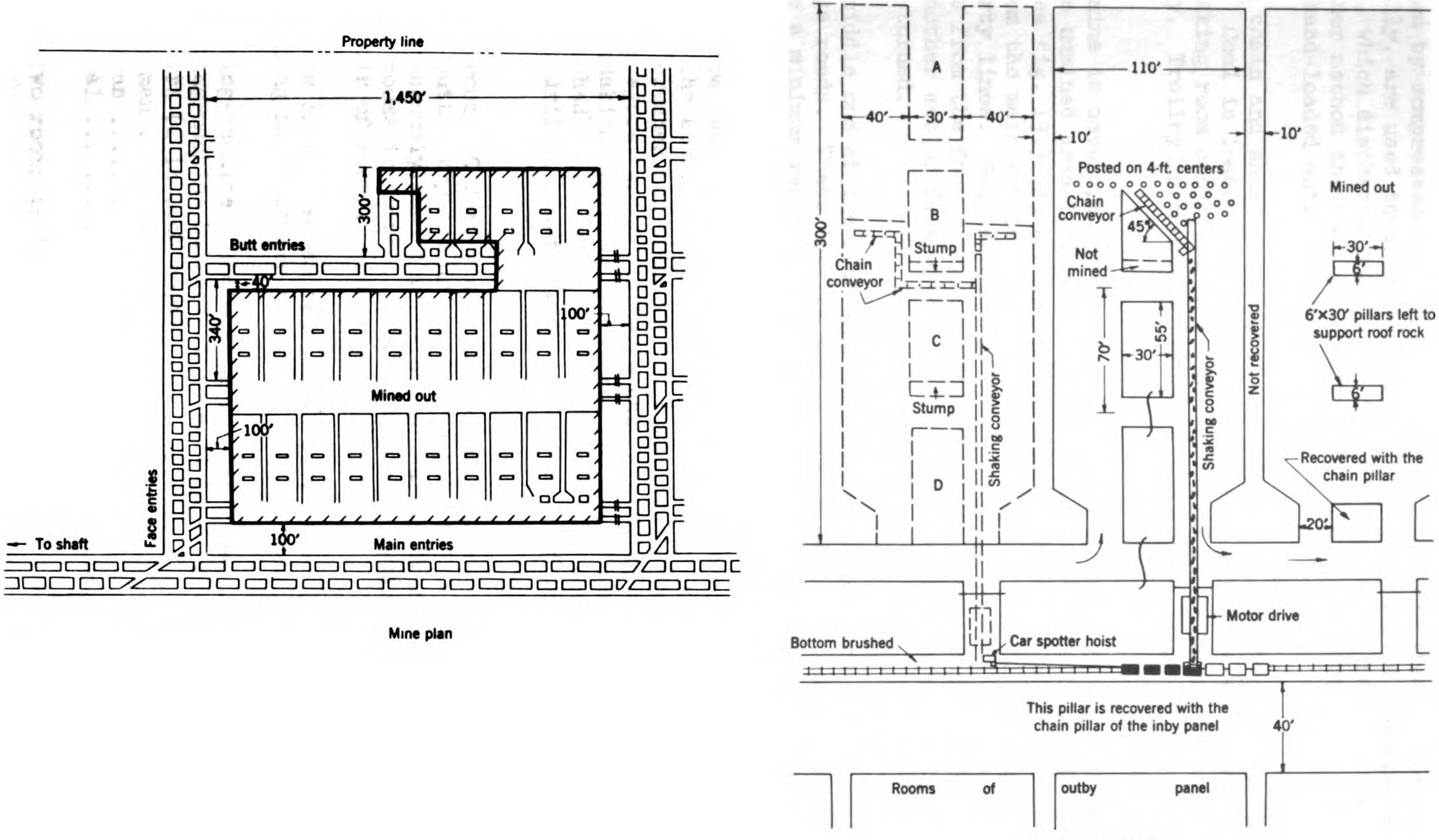
Mining Method

This mine was opened about 40 years ago and was developed by the room-and-pillar system of mining. Coal was loaded into mine cars by hand.

Originally the mine was developed in the Upper Freeport bed of coal. Later, the hoisting and air shafts were sunk to the Lower Kittanning coal bed, and until 1942 mining operations were conducted in the Freeport and Kittanning beds simultaneously. At the present time, mining operations are confined to the Lower Kittanning bed.

In the hand-loading sections of the mine the coal is top-cut by track-mounted arc wall machines equipped with 10-foot cutter bars and drilled with hand-auger drills. Permissible explosives are used to break the coal, which is hand-loaded into 1-ton mine cars. The bottom rock is brushed in all working places to provide about a 5-foot clearance.

Coal in the mechanized sections of the mine is mined by two methods. In one the coal is top-cut by cutting machines equipped with 6-foot cutter bars



Mine plan

Plan of pillar extraction

Figure 13. - Mining method at mine 51.

and drilled by compressed-air drills. Permissible explosives, detonated electrically, are used to blast the coal. The coal then is hand-loaded onto conveyors, which discharge into 1-ton mine cars placed in the butt entries. In the other method the coal is broken from the solid by pneumatic pick hammers and hand-loaded onto conveyors.

Both chain and shaking conveyors are used in the mechanized sections of the mine. Coal is loaded onto chain conveyors at the face and is discharged onto a shaking room conveyor, which transports it to 1-ton mine cars in the butt entry. Trolley locomotives transport the loaded trips to the shaft bottom.

The mine is developed by multiple main, face, and butt entries, which divide the unmined area into panels approximately 1,450 feet long by 340 feet wide. (See fig. 13.) Face entries, in sets of three, on 60-foot centers are turned from the main entries at intervals of 1,450 feet and are advanced to the property lines. Butt entries in sets of two on 60-foot centers are turned 90 degrees from the face entries at intervals of 340 feet and are driven 1,450 feet to another set of face entries. These butt entries are developed before rooms are turned.

The middle one of the face entries and the outby entry of the butt entries are haulage roads. These entries are driven 14 feet wide and are bottom-brushed to provide a minimum vertical clearance of 5-1/2 feet. The other entries are airways and are driven 20 feet wide. These airways are not brushed.

Entries are developed by two units. The first advances the headings into the coal, and the second, which works approximately 300 feet outby the face of the headings, brushes and prepares the haulageway. Coal is hand-loaded onto chain face conveyors, which discharge onto a shaking conveyor in the haulage entry. This shaking conveyor transports the coal to mine cars placed near the end of the brushed haulageway. The bottom rock in the haulageway is drilled with pneumatic drills, blasted with explosives, and loaded by hand into mine cars.

Pairs of rooms 40 feet wide, on 70-foot centers, are turned 90 degrees from the inby butt entry and driven to a depth of 300 feet. Two rooms are developed simultaneously, and the 30-foot pillar is extracted before the next outby pair of rooms is turned. A 10-foot pillar, which is not recovered, separates each pair of rooms. (See fig. 13.)

A unit crew in the mechanized panels comprises 10 men. In the sections where top-cutting machines are used, the crew is classified as follows:

Cutting-machine operators (1 in each room)	2
Cutting-machine helpers (1 in each room)	2
Loaders (2 in each room)	4
Boom man	1
Foreman	1
Total	10

Coal from the two rooms is transported to a common loading station operated by one boom man.

In sections where pneumatic pick hammers are used, the crew comprises the following:

Pick-hammer operators (2 in each room)	4
Loaders (2 in each room)	4
Boom man	1
Foreman	1
Total	10

The loaders and the pick-hammer operators alternate during the shift. Recently, automatic car spotters and car loaders were installed in some of the pick-hammer unit sections, which eliminates the need of a boom man. The automatic "boom boy" controls loading and spots the cars under the conveyor boom. Eventually, all mechanized sections will be equipped with these automatic car-loading units.

The coal in all mechanical sections is hand-loaded onto chain-face conveyors, which discharge onto a shaking conveyor along the left rib of the inby room. Chain conveyors transport the coal from the face of the outby room, through crosscuts, to the shaking conveyor, which discharges the coal into 1-ton mine cars. (Fig. 13.)

Pillar Extraction

When a pair of rooms is driven 300 feet to completion, the equipment in the outby room is stored in the butt entry and the equipment from the inby room and the entire crew of eight men is employed to extract the 30-foot pillars between the two rooms. Crosscuts driven on 70-foot centers separate the coal between the rooms into four pillars approximately 30 feet wide by 55 feet long. Successive cuts or lifts are taken off the pillars along a 45-degree face, and the coal is mined open-ended. Timbers are set on 4-foot centers across the rooms and along the pillar face. (See fig. 13.) The pillar face is approximately 42 feet long. Successive lifts are taken until all of the coal is extracted from pillar A. The lifts in the pick-hammer sections of the mine are 5 feet deep, and those in the sections where the coal is top-cut are 6 feet deep. All of the equipment is retreated as extraction progresses. Pillars B and C are extracted in the same manner as pillar A, except that a stump 6 feet by 30 feet is left at the outby end of these pillars to support the roof. The stump is not recovered. Pillar D is extracted to the room neck, and this stump is recovered with chain pillars. The roof rock in this mine is strong and often remains unbroken after the coal has been extracted from a pair of rooms.

The chain pillar between butt entries, the 40-foot barrier pillar between the room faces of the preceding panel and butt entries, and room-neck stumps are extracted by the room crew to within approximately 240 feet of the outby working pair of rooms.

A typical cycle of operation in a pneumatic pick-hammer section of the mine is as follows:

1. Set conveyors and timber.
2. Break and load coal.

1. Set conveyors and timber. - The face conveyors are set approximately 1 foot from the face. When the face is advanced 5 feet, the room conveyors are extended. The crews are responsible for extending the conveyors serving their rooms. Timbers are set on 4-foot centers along the face. These timbers are not recovered.

2. Break and load coal. - The coal is broken from the solid by pneumatic pick hammers and is hand-loaded onto chain conveyors. A room crew comprises four men - two pick-hammer operators and two loaders. These men alternate jobs at regular intervals throughout the working shift. The face is advanced 5 feet before the conveyors are moved ahead.

A typical cycle of operation in a section of the mine where the coal is top-cut by machine is as follows:

1. Set conveyors and timber.
2. Top-cut.
3. Drill.
4. Blast.
5. Load.

1. Set conveyors and timber. - The face conveyors are placed about 4 feet from the face to provide clearance for the cutting machine. Face conveyors are moved forward each cut, and the room conveyors are extended. Timbers are set on 4-foot centers along the face.

2. Top-cut. - The coal is cut in the top of the bed with cutting machines equipped with 6-foot cutter bars. There is very little clearance between the top of the machine and the roof, and conditions sometimes occur that necessitate brushing the bottom to provide clearance for the cutting machine. This machine is designed to operate where the coal bed is 28 inches thick. When bottom rolls, which are common in this mine, are encountered, they are removed with pick hammers to provide clearance for the machines. Cutting begins as soon as coal from one side of the face has been loaded and proceeds across the room as the coal is loaded.

3. Drill. - Pneumatic drills are used to prepare the face for blasting. Usually four holes 5 feet deep are drilled near the bottom of the bed.

4. Blast. - The coal is blasted with permissible explosive, which is detonated electrically. Each hole is charged with 1 or 1-1/2 sticks of explosive and fired singly. The coal is friable, and a minimum of explosive is required.

5. Load. - The room crew (four men) loads the coal after it has been blasted. The cycle of operation is continuous, and often cutting, drilling, and loading are carried on simultaneously along a room or pillar face.

Classification of Employees

Classification	Shift			Total
	1st	2d	3d	
Underground - mechanized units:				
Men on pick hammer crews	9	9	9	27
Men on machine crews	9	9	9	27
Foremen	2	2	2	6
Total	20	20	20	60
Other underground employees:				
Motormen	3	2	2	7
Brakemen	-	-	2	2
Wireman	1	-	-	1
Brattice man	1	-	-	1
Timbermen	2	2	-	4
Rockmen	4	4	-	8
Trackmen	1	1	1	3
Laborers	2	-	-	2
Repairman	1	-	-	1
Foremen	1	1	1	3
Total	16	10	6	32
Hand loaders, nonmechanized sections	44	-	-	44
Total underground employees	80	30	26	136
Surface employees:				
Superintendent	1	-	-	1
Weighmaster	1	-	-	1
Clerk	1	-	-	1
Hoisting engineers	2	1	1	4
Railroad-car handler	1	-	-	1
Slate pickers	2	2	-	4
Fireman	1	-	-	1
Blacksmith	1	-	-	1
Carpenter	1	-	-	1
Coal inspector	1	-	-	1
Cager	1	-	-	1
Helper	1	-	-	1
Greaser and coupler	1	-	-	1
Pumpers	1	1	-	2
Shop foreman	1	-	-	1
Total	17	4	1	22
Total employees	97	34	27	158

Summary

Percent of mine mechanized	70
Average daily production, mechanized units, tons	375
Average daily production, hand loading, tons	125

Number of mechanized units (1 top-cutting; 1 pick hammer)1/	2
Number unit-shifts worked per day	6
Average production per unit-shift, tons	62.5
Average production per conveyor-shift, tons	31.25
Average production, pick-hammer units per shift, tons	162
Man-shifts per day, pick-hammer units	29
Average production per man-shift, pick-hammer units, tons	5.6
Average production, machine cut units per shift, tons	213
Man-shifts per day, machine cut units	31
Average production per man-shift, machine cut units, tons	6.9
Man-shifts per day, mechanized units, underground2/	82.4
Average production per man-shift, mechanized units, underground, tons.	4.6
Total employees charged to mechanical units3/	97.8
Average production per man employed per shift, mechanical units, tons.	3.8

1/ One unit comprises two conveyors.

2/ Other underground employees chargeable to mechanized production - 22.4.

3/ Total surface employees chargeable to mechanized production - 15.2.

Mine 52

Mine 52 is in west-central Pennsylvania and operates in the Lower Kittanning bed of coal, which averages 38 inches thick in this area. The coal bed contains two thin bands of marcasite less than 1/2 inch thick (one near the top and the other near the bottom of the bed) and a thin shale parting approximately 7 inches from the bottom of the bed. These partings are mined with the coal and are removed in the surface cleaning plant. The strata immediately above and below the coal bed are carbonaceous shale and hard fire clay, respectively. The carbonaceous shale, which is about 2 inches thick, spalls and usually falls with each cut of coal. When this occurs, the shale is removed from the coal by hand and is gobbed in the mine. The principal roof strata comprise 15 to 30 feet of hard shale overlain by sandstone. This hard shale and sandstone provide a good roof throughout the mine, although main haulageways and air courses must be timbered carefully.

The mine is opened by a drift, an intake rock air slope, and a vertical return air shaft about 4 miles inby the drift portal. Approximately 102,000 cubic feet of air is circulated per minute through the mine by an exhausting, centrifugal fan located at the return air shaft.

An average of 2,100 tons of coal is produced per day in three shifts. The mine is 100 percent mechanized.

Mining Method

Mine 52 was opened in 1915, and the coal was hand-loaded into mine cars for many years. In 1940, mechanical loading equipment was installed, and operations now are completely mechanized.

Several systems of mining have been tried since the introduction of the mechanization program to determine the most efficient method of recovering coal. At present, the room-and-pillar system of mining is practiced, and pillars are extracted. The coal face is prepared for blasting with post-mounted electric auger drills and shortwall undercutting machines equipped with 6-1/2-foot cutter bars. Permissible explosives, detonated electrically, are used to break the coal, which then is loaded into 2-ton shuttle cars by crawler-mounted loading machines. The shuttle cars transport the coal from the face to loading stations, where it is discharged directly into 4-ton steel mine cars. Mine cars are spotted for loading by a hoist controlled by the shuttle-car operator. Loaded trips are transported to the tipple by trolley locomotives.

The mine is developed by multiple main and butt entries, which divide the areas to be mined into panels 3,000 feet long and 650 feet wide. Main entries are driven in sets of four on 50-foot centers, and butt entries, in sets of six on 50-foot centers, are turned 90 degrees to the main entries at intervals of 1,400 feet. Butt entries are driven 12 and 14 feet wide for a distance of 3,300 feet to the inby end of the panel. The haulage entries are 12 feet wide and are bottom-brushed to provide a minimum vertical clearance of 5-1/2 feet above the rail. Air courses, which are 14 feet wide, are not brushed. (See fig. 14.)

Butt entries are developed by a conveyor unit, and rooms 14 feet wide are turned at right angles to the inby butt entry on 60-foot centers as butt entries advance. After six rooms have been turned, an operating unit comprising nine men, a crawler-mounted loading machine, one shortwall undercutting machine, one post-mounted electric drill, and two battery-operated shuttle cars is employed to develop the rooms and extract the room pillars. Rooms are developed and pillars are extracted in the inby panel (panel A, fig. 14) as the butt entries advance, and in the outby panel (panel B, fig. 14) on retreat from the butt entries. Adjacent panels between the butt entries are separated by a barrier pillar ranging in width from 50 to 100 feet, depending on physical conditions in the panels. The width of this pillar is determined by the elevation of the room faces in each panel. If the outby panel is higher, the pillar separating the room faces is approximately 100 feet wide to prevent the flow of water from the worked-out panel into the operating panel. If the two panels are approximately the same elevation, or the worked-out panel is lower, the barrier pillar is about 50 feet wide, and some of the rooms of the operating panel are driven to the worked-out area. Consequently, the depth of rooms in a panel adjacent to a worked-out area ranges from 650 to 700 feet. Barrier pillars 300 feet wide separate the panels from the main entries. It is planned to recover these pillars on retreat from this section of the mine.

Pillar Extraction

Experience at this mine has shown that the most efficient performance is obtained by advancing six rooms and retreating on three pillar faces. Thus there are at least nine working places per unit at all times.

The coal between rooms is divided into parallelogram-shaped pillars, about 46 feet long and 46 feet wide, by crosscuts driven on 60-foot centers. (See fig. 15.) These pillars are mined by taking successive 6-1/2-foot cuts off the inby end until the coal in the pillar has been recovered. The last two rows of pillars (E and F, fig. 15) in each set of rooms are not recovered until the next set of six rooms (rooms 63 to 68, inclusive) has been driven to a depth of 300 feet. These two rows of pillars protect rooms 61 and 62, which are shuttle-car roadways, until the pillars of the preceding rows have been recovered.

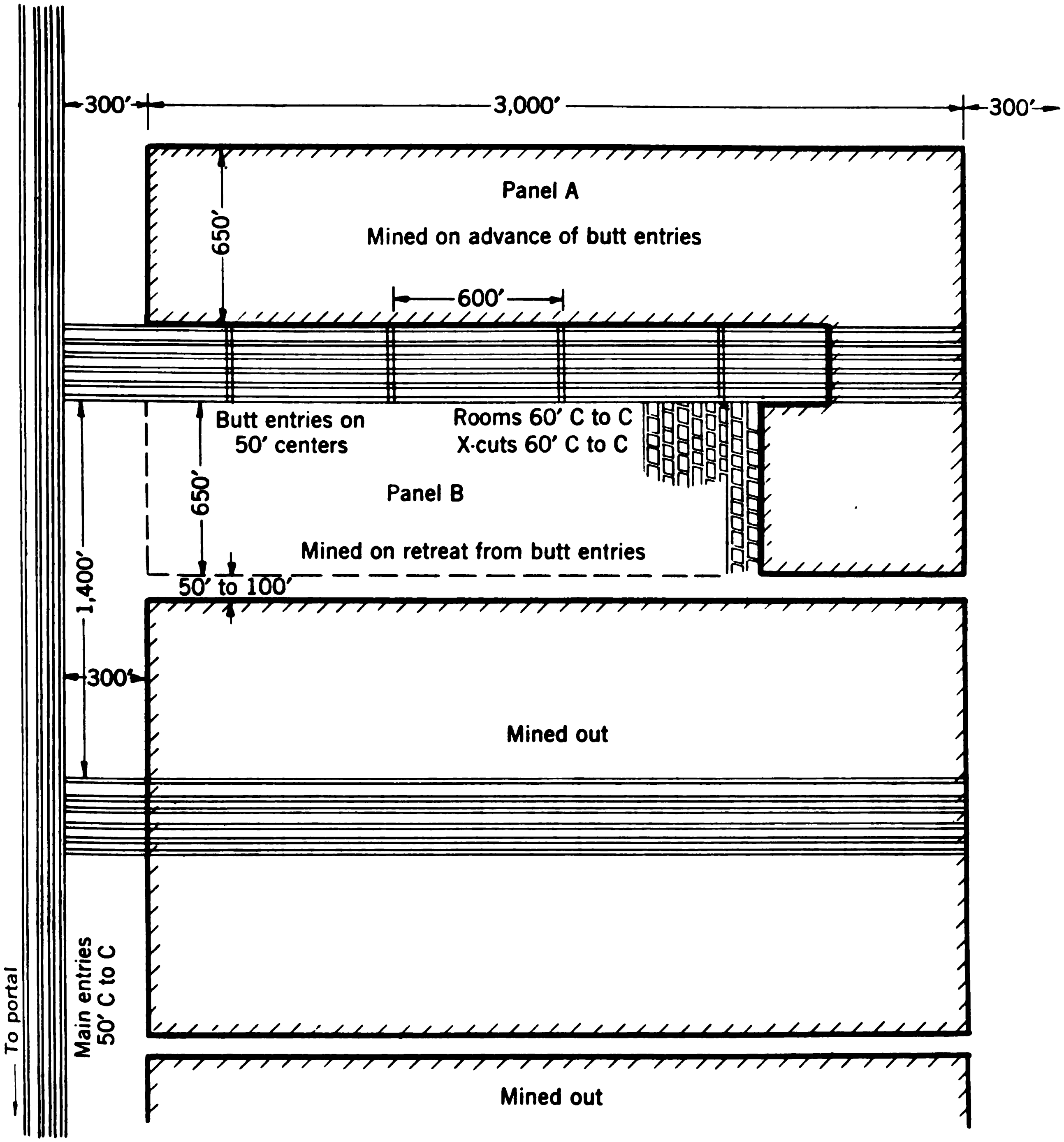


Figure 14. - Mining method at mine 52.

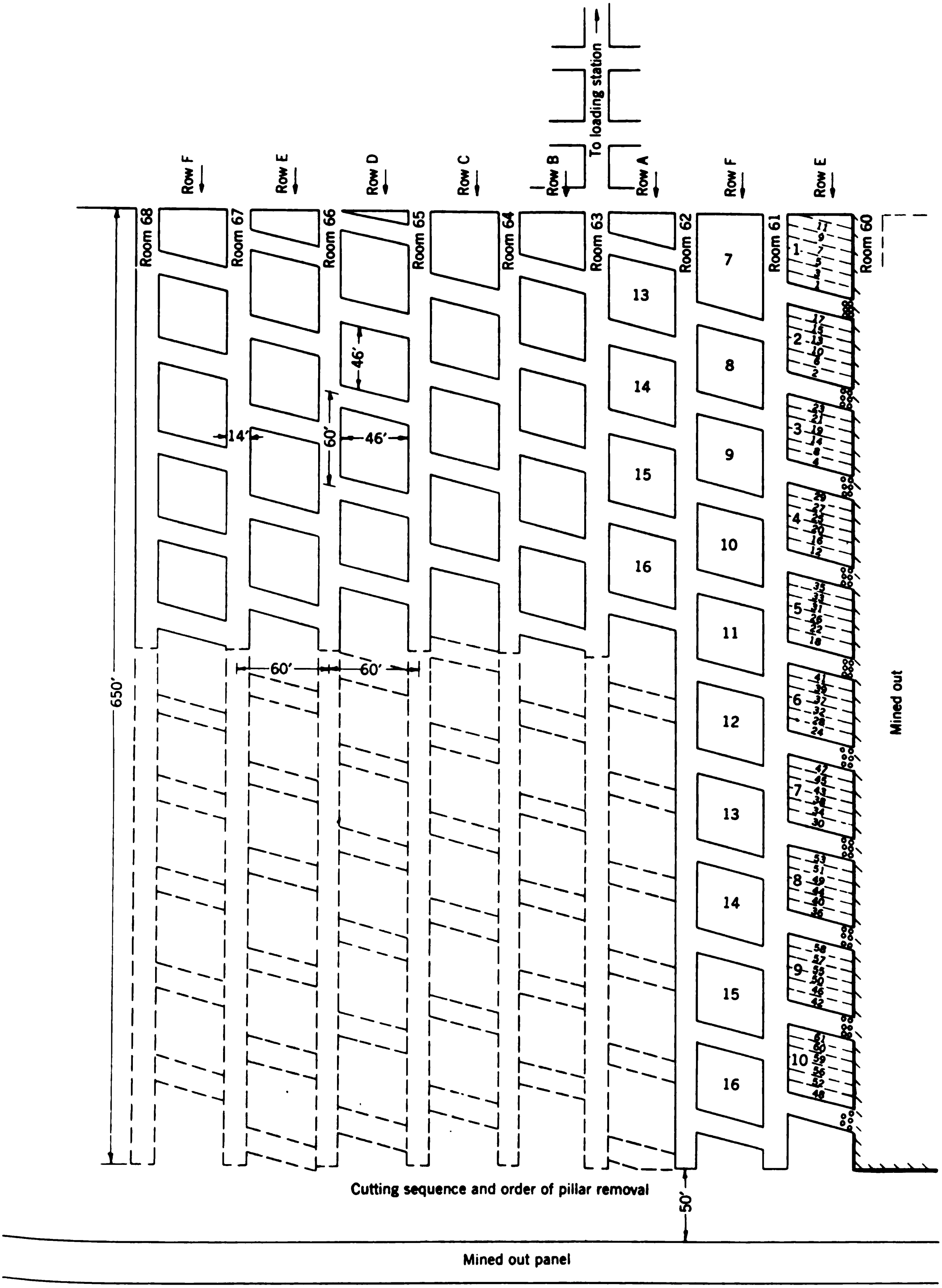


Figure 15. - Pillar extraction at mine 52.

Pillar extraction begins in pillars 1, 2, and 3, row E, and is timed to assure effective roof control. The sequence of cutting in pillar extraction is shown in figure 15. The first six pillars are recovered in row E, and then mining is begun in the first three pillars of row F. Thus, pillars 7, 8, 9, and 10 in row E and pillars 7, 8, 9, and 10 in row F are mined together. This order of pillar extraction is followed throughout the mine. This system establishes a pillar line approximately 70 degrees from the butt entry course. Operations are planned so that six rooms always are advancing ahead of pillar rows that are being extracted.

In order to protect the workmen from roof falls, it is essential that three or more cuts remain in the inby pillar when the last cut is made in the most outby pillar in the row. For example, in figure 15, pillar 2, row E, has three cuts remaining when the last lift is taken from pillar 1. The section foreman is responsible for maintaining the proper timing schedule.

The roof rock is strong and usually remains unbroken until a row of pillars has been mined. The first six rows of pillars in panel A in figure 14 can be removed before the roof rock breaks. After the first fall, succeeding falls usually occur after each row of pillars is removed. If the overhanging rock does not break after one or two rows of pillars has been removed, bottom heaving is likely to occur in the unmined pillar rows. When the bottom heaves, a great deal of trouble results because of the limited clearance between the machines and the roof rock. When excessive top pressure from overhanging roof rock occurs, it is often necessary to weaken the supports to get a fall that will relieve the weight.

Falls are well controlled and little coal is lost because of premature falls. The crosscuts between rooms are staggered (see fig. 15) to prevent falls from extending through the crosscuts. In this method of mining, difficulties occasioned by roof pressure and water are encountered in the inby end of panel B adjacent to the worked-out area. However, mining is on retreat from this area, and the effect of these difficulties is minimized.

Over-all recovery at this mine is approximately 75 to 80 percent. The recovery in panels is about 95 percent.

A unit crew in a room-and-pillar section of the mine comprises the following men:

Drill operator	1
Cutting-machine operator	1
Cutting-machine helper	1
Shotfirer	1
Loading-machine operator	1
Loading-machine helper	1
Shuttle-car operators	2
Timberman (first shift only)	1
Foreman	1/2
Total	9-1/2

The cycle of operation in a pillar section is as follows:

1. Drill.
2. Cut and timber.
3. Blast.
4. Load coal.

1. Drill. - The coal is drilled with post-mounted, electric, auger-type drills. Eight holes, on 5-foot centers, are drilled near the top of the bed at an angle to intersect the carbonaceous shale roof. The drill post is mounted on a sled, which can be moved from one hole to another without removing the drill. This type of mounting enables one man to handle the drill. A rubber-tired, cable-reel truck transports the drill from one working place to another.

2. Cut and timber. - The coal is bottom-cut with shortwall cutting machines equipped with 6-1/2-foot cutter bars. These machines are transported on crawler-mounted trucks. Two men comprise a cutting crew. They also timber the places before and after cutting. The pillar faces are open-ended, and the undercut is approximately 46 feet long.

3. Blast. - The coal is blasted with permissible explosive, detonated electrically. Usually one stick of explosive is placed in each hole, and the holes are fired singly.

4. Load coal. - Crawler-mounted loading machines load the fallen coal into 2-ton shuttle cars, which transport it to the loading station and discharge it into 4-ton steel mine cars. Two shuttle cars operate with each loading machine. Occasionally, when long hauls are necessary, three shuttle cars are used with each loading machine. The shuttle cars are powered by storage batteries. Four men comprise a loading-machine crew: Loading-machine operator, loading-machine helper, and two shuttle-car operators.

Classification of Employees

Classification	Shift			Total
	1st	2d	3d	
Underground - mechanized units:				
Drill operators	6	6	6	18
Cutting-machine operators	6	6	6	18
Cutting-machine helpers	6	6	6	18
Shotfirers	6	6	6	18
Loading-machine operators	6	6	6	18
Loading-machine helpers	6	6	6	18
Shuttle-car operators	12	12	12	36
Timbermen	6	-	-	6
Foremen	4	2	2	8
Conveyor men	8	8	-	16
Total	66	58	50	174

Classification	Shift 1st	2d	3d	Total
Other underground employees:				
Mechanics	6	5	3	14
Wiremen	2	-	-	2
Trackmen	2	-	-	2
Timbermen	6	-	-	6
Laborers	8	-	-	8
Supply men	-	-	2	2
Motormen	3	2	1	6
Brakemen	1	1	1	3
Pumper	1	-	-	1
Fire bosses	1	1	1	3
Rock dusters	2	-	-	2
Rockmen	4	4	4	12
Mine foreman	1	-	-	1
Total	37	13	12	62
Total underground employees	103	71	62	236
Surface employees:				
Superintendent	1	-	-	1
Weighmaster	1	-	-	1
Clerks	3	-	-	3
Railroad-car handlers	1	1	-	2
Blacksmith	1	-	-	1
Carpenter	1	-	-	1
Lamp men	1	1	1	3
Car repairmen	2	-	-	2
Yard supply men	2	2	-	4
Tipplemen	15	15	-	30
Yard foreman	1	-	-	1
Total	29	19	1	49
Total employees	132	90	63	285

Summary

Percent of mine mechanized		100
Average daily production, mobile machines, tons	1,870	
Average daily production, conveyors, tons	230	
Total average daily production, tons		2,100
Number mechanized units, mobile machines	6	
Number mechanized units, conveyors	2	
Total number mechanized units		8
Number unit-shifts worked per day, mobile machines	18	
Number unit-shifts worked per day, conveyors	4	
Total number unit-shifts worked per day		22
Average production per unit per shift, mobile machines, tons	103.9	
Average production per unit per shift, conveyors, tons	57.5	
Average production per unit per shift, tons		95.5
Man-shifts per day, mobile machines	158	
Man-shifts per day, conveyors	16	
Total man-shifts per day		174

Average production per man per shift, mobile machines, tons	12.1	
Average production per man per shift, conveyors, tons	14.7	
Average production per man per shift, mechanized units, tons		12.1
Hours worked per shift		9
Total man-shifts per day, underground		236
Average production per man per shift, underground, tons		8.9
Total employees		285
Average production per man employed per shift, tons		7.4

Mine 53

Mine 53 is in southern West Virginia and operates in the Pocahontas No. 3 coal bed, which ranges in thickness from 4-1/2 to 5-1/2 feet. A middle band of bone coal separates the coal bed into two benches. A stratum of shale ("draw slate") 2 to 8 inches thick lies immediately above the coal. The strata above this shale comprise sandy shale, fire clay, coal, sandstone, and gray shale. The coal bed outcrops on the mountainside, and the overburden ranges in thickness from a few feet at the outcrop to approximately 800 feet under the mountain peaks. The roof is weak in some sections of the mine, and it is necessary to set crossbars every 2-1/2 feet. However, in the mechanized sections the roof rock is fairly firm and is supported by props and crossbars set on 4-foot centers.

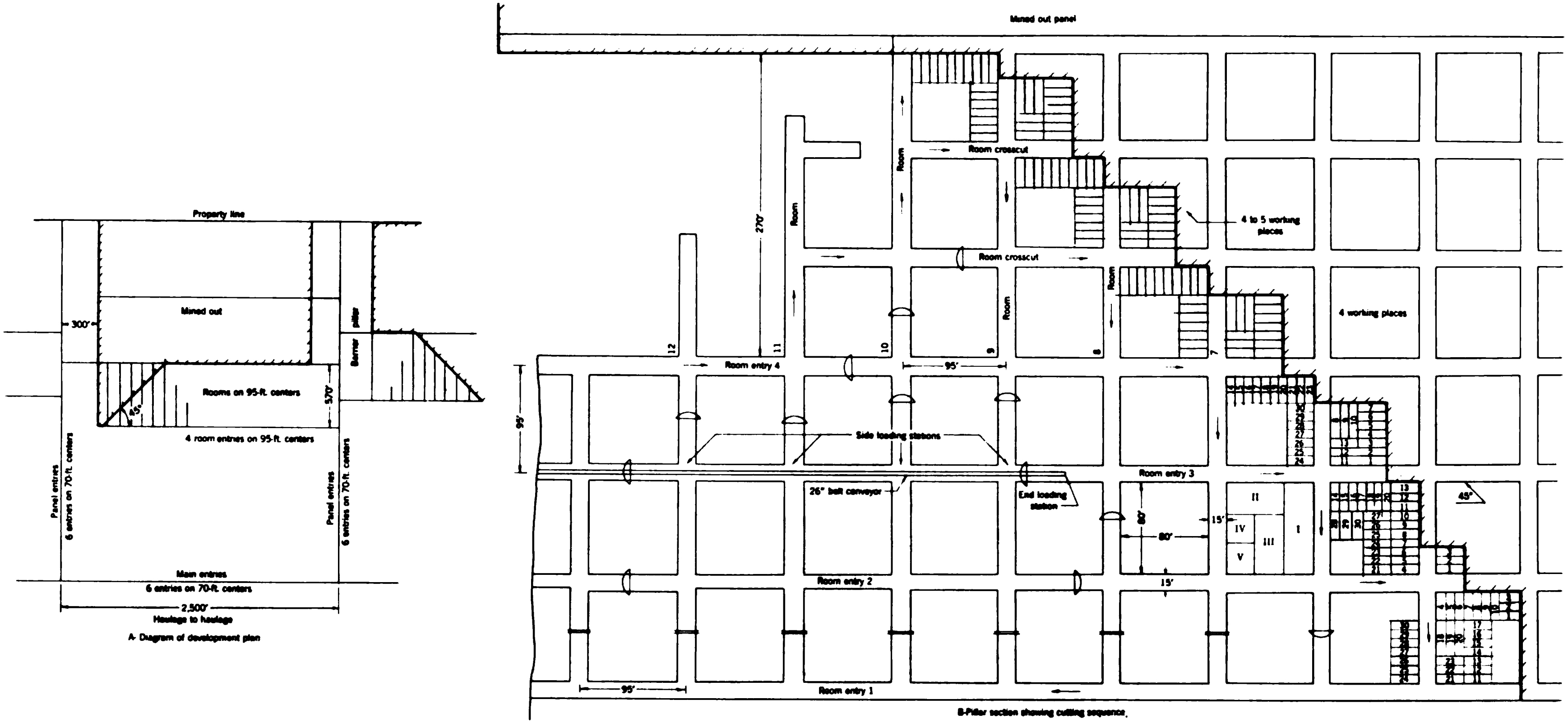
The coal bed is underlain by a stratum of fire clay, which, when dry, is a good roadway for trackless equipment. However, this fire clay becomes soft when wet and will not support the shuttle cars. Where this condition exists, the roadway is covered with dry fill.

The average production from the mechanical sections of the mine is 3,480 tons of raw coal (2,400 tons of clean coal) a day in two 8-hour shifts. The mine is about 50 percent mechanized.

Mining Method

This mine was originally developed by the room-and-pillar system of mining, and hand loading into mine cars was practiced. In 1934, part of the mine was mechanized, and coal was loaded into mine cars with mobile loading machines. At present both track-mounted and trackless types of equipment are used in the mechanical sections. In some of the trackless sections coal is loaded into 4-ton, cable-reel, shuttle cars by crawler-mounted loading machines and is transported to loading stations, where the coal is transferred to 5-ton steel mine cars. In other trackless sections the coal is loaded into shuttle cars and transported to panel belt conveyors, which transport the coal to mine cars in the main entry. Only the system of mining in belt-conveyor sections is discussed in this report.

Belt-conveyor sections are developed by six parallel main entries driven on 70-foot centers. Panel entries, in sets of six on 70-foot centers, are turned at right angles from the main entries every 2,500 feet and are driven to the property lines. Main entries and panel entries are bottom-brushed to provide minimum clearance of 6 and 5 feet, respectively. Room entries are driven on 95-foot centers both to the right and left off the panel entries. These entries are staggered, as shown in the plan of development (fig. 16A).



A- Diagram of development plan

B-Pillar section showing cutting sequence.

Figure 16. - Mining method at mine 53.

Panel entries are driven to the property lines before room entries are turned. However, in some cases a panel between the main entries and property line is developed to maintain production during the advance of the panel entries. Usually the first room entries are turned at the inby end of the panel, and coal in the panel adjacent to the boundary pillar is mined first.

Room entries are developed in sets of four and are driven 15 feet wide. The length of these entries depends on the area being developed. Normally, room entries are driven to within 300 feet of the adjacent panel entries, a distance of 1,850 feet. Crosscuts driven on 95-foot centers connect the room entries. Thus, each chain pillar is a square block 80 by 80 feet.

Entry 3 (fig. 16B) is the haulage entry and is equipped with a 30-inch belt conveyor. The belt tailpiece is moved forward 190 feet at a time as the room entries advance and is withdrawn in 95-foot sections as mining in the panel retreats. The coal mined from the entries on advance and that from the chain pillars, which are mined on retreat, is transported by shuttle cars to the end loading point. Coal from the rooms and room pillars is transported in shuttle cars and transferred to the belt at side loading stations.

Rooms 15 feet wide are turned at right angles to the inby room entry and driven 285 feet. The rooms are driven on 95-foot centers in line with the crosscuts connecting the room entries. Rooms are connected by right-angle crosscuts driven on 95-foot centers. Therefore, room pillars are 80 feet square - the same size as room-entry chain pillars. The three inby rooms are developed before pillar mining is started. When these rooms have been advanced 285 feet, or to the inby "worked-out" panel, pillar extraction is begun in the inby pillar between the two inby rooms. A pillar line is established and maintained approximately 45 degrees to the room entries. (See fig. 16B.)

Approximately 70 percent of the coal in a panel is mined from pillars, and 30 percent is mined from entries, rooms, and crosscuts.

Pillar Extraction

Each pillar or block comprises five open-ended lifts. Alternate lifts are taken on the gob sides of the block until the pillar is completely extracted. Each lift comprises 3 to 10 cuts 25 feet wide and 8 feet deep. The first lift in a pillar is started from a room crosscut or room entry. The second lift is started from the outby room and is driven across the inby end of the pillar to the first lift. Figure 16B shows the order of mining the lifts in each pillar or block and the sequence of cuts.

At the time of this study, pillar mining had not progressed very far, and the falls in the retreat sections were not normal. In one panel, an entire pillar had been removed, and the roof was still standing. In other parts of the mine where pillar mining is more advanced, falls occur as soon as a lift is completed and the timber supports removed.

Timbers are not recovered in most sections of this mine because of poor roof conditions. However, the roof in the section described in this report is good, and timbers are recovered in retreat mining. A working section usually comprises nine places - six pillar, two room, and one crosscut. An operating unit usually is 13 men, 2 loading machines, 2 cutting machines, 2 drills, 2 shuttle cars, and a belt conveyor. The men are classified as follows:

Loading-machine operators	2
Cutting-machine operators	2
Cutting-machine helpers	4
Shotfirers	2
Shuttle-car operators	2
Foreman	1
Total	13

The units are divided, and one-half the unit, comprising six men, one loading machine, one shuttle car, one cutting machine, and one drill, mines the three chain blocks and one room block along the pillar line. The other half unit works in two room blocks and advances two rooms. When a crosscut is being driven, this unit is assigned five working places.

The cycle of operations is as follows:

1. Timber.
2. Cut.
3. Drill.
4. Blast.
5. Load coal.

1. Timber. - Two crossbars are set per cut. These crossbars are temporarily supported by steel jacks. The jacks are replaced by timber legs after the face has been advanced. Props are set as needed. The cutting-machine crew, which comprises three men, does the timbering. Occasionally the loading-machine operator and shuttle-car operator set props or crossbars where they are needed.

2. Cut. - The coal bed is undercut in the bottom by shortwall machines equipped with 8-1/2-foot cutter bars. The depth of cut averages 8 feet. Cutting machines are transported between working places by crawler-mounted trucks.

3. Drill. - Hand-held, electric, auger-type drills are used to drill the coal. These are carried on the cutting-machine truck, and the holes are drilled by the cutting-machine crew. Four holes are drilled immediately above the bone parting and three holes immediately below the parting.

4. Blast. - The coal is blasted with permissible explosives detonated electrically.

5. Load coal. - The fallen coal is loaded into shuttle cars by crawler-mounted loading machines. The shuttle cars transport the coal to the entry, where it is discharged onto belt conveyors. The belt conveys the coal to the panel entries, where it is loaded into 5-ton steel mine cars and then transported in trips to the tipple by trolley locomotives. The main line haul is about 6 miles from the new belt section of the mine to the tipple.

Classification of Employees

Classification	Employees	
Underground - mechanized units:		
Track-mounted units		176
Shuttle-car units		54
Total		230
Hand-loading units:		
Cutting-machine operators		6
Loaders		246
Laborers		100
Total		352
Other underground employees:		
Rockmen (mechanized units)		50
Motormen		44
Wiremen		44
Timbermen		10
Clean-up men		8
Drainage men		21
Ventilation men		18
Laborers		55
Total		250
Total underground employees		832
Surface employees:		
Tipplemen		20
Rock pickers		62
Tipple mechanics		4
Rock-disposal men		2
Supply men		6
Laborers		14
Shopmen:		
Cutting machines	6	
Loading machines	18	
Conveyors	8	
Locomotive and shuttle cars	26	
Pumps	2	
Mine cars	4	
Blacksmiths	6	
Others	12	
Total		82
Boilerhouse		14
Repairmen in powerhouse		2
House- and townmen		8
Shop foremen		4
Engineers		2
Clerks		8
Watchmen		2
Supervision		6
Total		236
Total employees		1,068

Percent of raw-coal production from mechanized units 60

Summary

	Raw coal	Clean coal
Average daily production, tons	5,810	4,800
Average daily production, mechanized units, tons	3,480	2,400
Number unit-shifts per day	24	24
Average production per mechanized unit per shift, tons	145	100
Man-shifts per day, mechanized units	230	230
Average production per man per shift, mechanized units, tons	15.1	10.4
Other man-shifts per day, underground	250	250
Other man-shifts per day, underground charged to mechanized units	170	170
Total underground man-shifts charged to mechanized units, tons	400	400
Average production per man per shift underground charged to mechanized units	8.7	6.0
Surface employees	236	236
Surface employees charged to mechanized units	142	142
Total employees charged to mechanized units	542	542
Production per man employed per shift, mechanized units, tons	6.4	4.5
Total employees, mechanized mining and hand-loading		1,068
Production per man employed per shift, tons	5.4	4.5

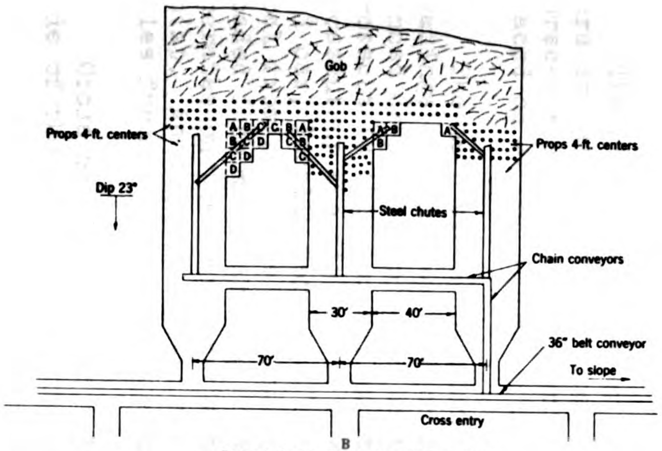
Mine 54

This mine, which is situated in Wyoming, operates in the Willow Creek coal bed. This bed, which dips 23 degrees in a westerly direction, outcrops on the west side of a high ridge. The mine is entered at the outcrop by a slope driven down the dip in the coal bed. At the time of this study the slope was 3,900 feet long and was being advanced under approximately 1,500 feet of overburden. The overburden increases about 40 feet for every 100 feet of slope advance.

The thickness of the coal bed ranges from 9 to 16 feet. There is a shale parting about 5 feet above the bottom, and at some places there are one or more thin shale lenses at irregular positions in the bed. These impurities are removed at the face and on picking tables in the tipple. The overlying strata are fragile shale and hard sandstone. The bottom is soft shale and hard sandstone.

The mine is 100 percent mechanized and produces an average of 1,100 tons per day in three shifts. Coal is hoisted during the first two shifts. The slope and cross entries are developed and the material distributed to working places during the third shift. All coal is transported from the slope opening to the tipple by a 48-inch belt conveyor 400 feet long.

The mine is ventilated by a 95,000-cubic-foot-per-minute exhaust fan. The fan is at the air shaft, which is 125 feet deep and connected to the slope airway. The air shaft is circular and lined with 3/4-inch steel plates concreted in place. Undercasts at intersections of cross entry haulageways and



B
Removal of room pillars and sequence of mining

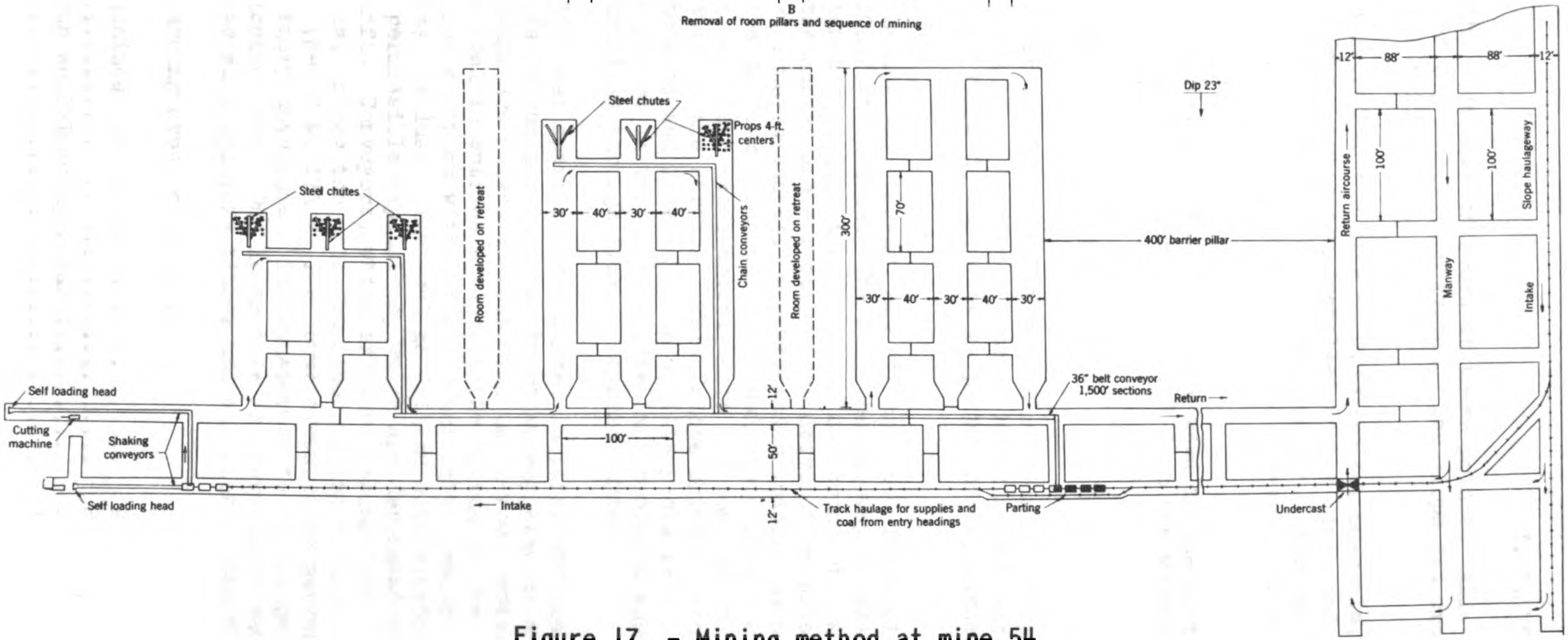


Figure 17. - Mining method at mine 54.

the slope air course obviate the necessity of doors at these points. All haulageways are on the intake of the ventilation system. The slope and cross entries are rock-dusted at regular intervals.

Power is purchased and delivered to the mine at 2,300-volts, 60-cycle, 3-phase, alternating current. Transformers are installed in the mine, and power for underground operations is 220-volt alternating current. The main hoist, which is rated at 800-horsepower, is driven by two 2,300-volt, alternating-current motors.

Track gage is 42 inches, and 60-pound steel rails are used in the slope haulageway. Belt conveyors in cross entries transport coal from the working places to mine cars on the slope partings.

Mining Method

The room-and-pillar system of mining is followed, and room and entry pillars are extracted on retreat from cross entries. Entries are timbered with three-piece sets, and the roof in rooms is supported by props and cap pieces placed on 4-foot centers.

The main slope comprises haulageway, manway, and air course. These slope headings are 12 feet wide on 100-foot centers. The slope haulageway is advanced down the dip for a distance of 100 feet beyond the last crosscut. A crosscut is then turned, and the manway and air course are driven from this crosscut up the dip to the next outby crosscut. A combination loading machine and car, locally termed a "slope driving machine," loads and transports the coal from the slope heading to the above cross entry, where the coal is unloaded into mine cars and hoisted to the surface. This "slope driving machine" operates on the track and is hoisted and lowered by an auxiliary electric hoist. An electric blower fan placed in the entry at the last crosscut supplies fresh air to the slope headings through flexible canvas tubing.

Cross entries are about 350 feet apart and are turned in pairs off one side of the main slope, which is driven parallel to the mined-out area of an adjacent abandoned mine. Headings are driven 12 feet wide on 62-foot centers on the strike of the bed. The coal in entries is cut in the bottom of the bed by shortwall cutting machines equipped with 8-foot cutter bars. Water is used on the cutter bars to allay the dust. The coal is drilled with electric auger drills and blasted with permissible explosives, which are detonated electrically during the working shift. Conveyors, which are the shaking type equipped with self-loading heads, convey the coal from the heading to mine cars in the entry at the crosscut. (See fig. 17A.) The lower cross entry serves as the haulageway, and coal from entry development is transported to the slope in mine cars by storage-battery locomotives. One locomotive is operated in each cross entry, and this locomotive also delivers timber and supplies to the face.

The equipment used in advancing cross entries is:

Shortwall cutting machines	2
Electric drills	2
Shaking conveyors with self-loading heads	2
Cross conveyor	1

The average crew of men assigned to cross entry development is:

Cutting-machine operators (1 in each heading)	2
Cutting-machine helpers (1 in each heading)	2
Conveyor operator	1

Rooms are turned on 70-foot centers from the outby cross entry. The first room is 400 feet inby the main slope. Rooms, which are developed in groups of three, are driven up the dip at 90 degrees with the strike of the bed. A pillar of coal 140 feet wide is left between each group of three rooms. The height of the room usually is the thickness of the coal bed, except in areas where weak shale roof is encountered. In such areas coal is left for roof. Where the bed reaches the maximum thickness of 16 feet, rooms are driven 8 feet high to depth, and the top coal is taken down on retreat from the roof. Cross-entry pillars are extracted on retreat.

In the operation of a three-room unit, a crew of men is assigned to each room. Steel chutes, which facilitate the flow of fallen coal, extend from the face of the room to a chain conveyor in the inby crosscut. (See fig. 17A.) This conveyor extends across the three rooms to a chain conveyor in the outby room and the coal is conveyed to a 36-inch belt conveyor in the cross entry. The belt conveyors are extended in 150-foot sections to a total length of 1,500 feet. At the time of this study, the coal in one of the cross-entry sections was conveyed to the slope parting by two 1,500-foot belt-conveyor units placed in tandem. Coal is loaded into cars at the parting and is hoisted in four-car trips. Solid steel cars having a rated capacity of 5 tons are loaded with an average of 4-1/2 tons of coal. The average production, 1,100 tons in two 7-hour shifts, is transported in 52 cars, an average of 13.1 tons per car per shift.

The mining cycle in rooms is (1) timber, (2) drill and charge holes, (3) place steel chutes at face, (4) blast, and (5) load.

The average crew of men assigned to a room is:

Drillers to drill, blast and timber	2
Loaders to load coal, timber, place chutes and extend conveyors	3
Total	5

Pillar Extraction

Extraction of pillars is begun in the inby rooms after the coal in all rooms off the cross entry has been extracted. The 140-foot pillars between the three-room units are extracted on retreat. (See fig. 17A.) Room pillars are 70 feet long and 40 feet wide. Extraction is begun at the inby end of the pillar, and mining is in successive steps, as shown in figure 17B. The fallen coal is shoveled and pushed over the steel chutes that are placed in the rooms and along the working faces to cross-chain conveyors in the next outby crosscut. The cross conveyor and room conveyor transport the coal to the belt conveyor in the cross entry. In new development, cross entries will be driven to boundaries and rooms and pillars will be mined on retreat.

Classification of Employees

Classification	Shift			Total
	1st	2d	3d	
Underground - mechanized units:				
Entries:				
Cutting-machine men	2	2	2	6
Cutting-machine helpers	2	2	2	6
Conveyor men	1	1	1	3
Rooms-and-pillars:				
Drillers and shooters	18	18	-	36
Loaders	27	27	-	54
Total	50	50	5	105
Other underground employees:				
Hoisting engineers	1	1	1	3
Motormen	3	3	1	7
Ventilation men	1	1	-	2
Timbermen	2	2	1	5
Rope riders	1	1	1	3
Car trimmers	3	3	-	6
Foremen	2	1	1	4
Total	13	12	5	30
Total underground employees	63	62	10	135
Surface employees:				
Hoisting engineers	1	1	1	3
Weighmen	1	1	-	2
Shop and repairmen	4	-	-	4
Tipple foremen	1	1	-	2
Tipplemen	5	5	-	10
Total	12	8	1	21
Total employees	75	70	11	156

Summary

Percent of mine mechanized	100
Average daily production, raw coal, tons	1,100
Average daily production, raw coal, tons, room-and-pillar	900
Average daily production, raw coal, tons, development	200
Number mechanized units, rooms[1]	3
Number mechanized units, shifts per day	6
Number of conveyors, rooms[2]	3
Number of conveyor shifts per day, rooms	6
Average tons per conveyor shift, rooms	150
Number of entry conveyors	2
Number of entry conveyor shifts per day	6
Number of tons per entry conveyor shift	33
Number of belt conveyors, entries	2
Number of belt conveyor shifts, entries	4
Average tons per belt conveyor shift	225

See footnotes on following page.

Average number of men on mechanized units, rooms	90
Average production per man per shift on mechanized units, rooms, tons.	10
Average production per man per shift on mechanized units, entries, tons	13.3
Average number of men on mechanized units	105
Average production per man per shift, mechanized units, tons	10.5
Total employees underground	135
Average production per man per shift, underground, tons	8.1
Total employees, underground and surface	156
Average production per man per shift, tons	7.1

1/ A unit is three rooms.

2/ One conveyor for a three-room unit.

Mine 55

The coal bed, which dips 20 degrees in a westerly direction, outcrops on the east side of a high ridge. The main opening is a slope driven in the coal on the dip of the bed. This mine is in western Wyoming.

The thickness of the bed ranges from 60 to 64 inches and usually contains 1 to 2 inches of bony coal immediately under the roof. This bony coal falls when the coal is mined and is removed on picking tables in the tipple. The roof is hard, firm sandstone. The bottom is soft shale, which heaves slightly, but this does not cause serious difficulty in mining. "Want" areas and local rolls present problems in the operation of this mine.

The production of the mine at the time of this study averaged 700 tons a day in three shifts. The mine is 100 percent mechanized, and coal is loaded and hoisted on all shifts. The greater part of the output is produced during the first two shifts, and coal loaded during the third shift is hoisted and stored in mine cars on the surface until the following day. All coal is transported from the mine to the tipple in trips of 21 cars over a surface tramway 10,000 feet long.

Ventilation is furnished by a 75,000-cubic-foot-per-minute exhaust fan. The fan is at the air shaft, which is 40 feet deep and connected to the slope airway. All haulageways are on the intake of the ventilation system.

Rock dusting is done in the main slope and cross entries by means of a portable rock-dusting machine mounted on a platform car.

Excessive amounts of water are not encountered in the mine, and water not used for sprinkling at the working faces is pumped to the surface by three 25-horsepower, 110-g.p.m. pumps placed at sumps along the slope.

Power is purchased and delivered to the mine at 2,300-volts, 3-phase, 60-cycle, alternating current. The main hoist is driven by one 450-horsepower, 2,300-volt, alternating-current motor, and a 300-k.w. motor generator furnishes 250-volt direct current for underground haulage and use at the working faces.

Track gage is 42 inches, and 40-pound steel rails are used in the slope and on haulageways.

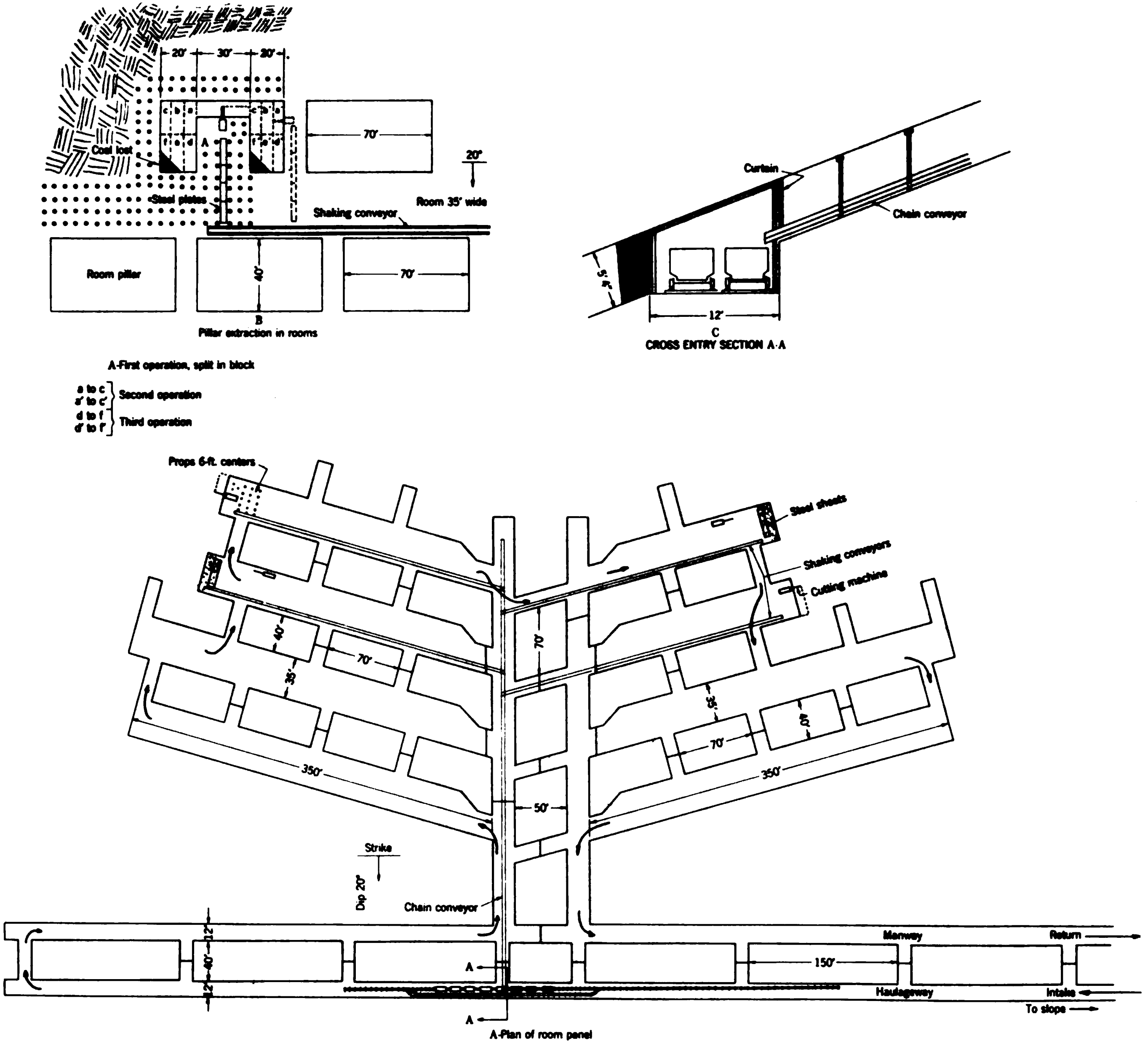


Figure 18. - Mining method at mine 55.

Mining Method

The room-and-pillar system of mining is followed, and pillars are extracted on retreat from a panel. The slope headings are 12 feet wide on 62-foot centers. At the time of this study, the slope was 4,000 feet long and was advancing under 1,400 feet of cover. The overburden increases at a rate of about 20 feet for every 100 feet of advance. The mine is developed by driving cross entries in pairs along the strike of the bed from each side of the main slope. These entries are driven 12 feet wide on 52-foot centers. Panel or room entries are turned off the cross entries at intervals of approximately 700 feet and are driven up the dip to within 50 feet of the next outby cross entry. Rooms are turned up the dip at an angle of 15 degrees from the strike of the bed, both to the right and left of the panel entries. The depth of rooms is usually 350 feet. The first rooms are turned approximately 100 feet inside the cross entries, and rooms are developed in pairs, each pair of rooms comprising an operating unit. Pillars are extracted as the rooms are completed, starting recovery at the inby end of the panel. (See fig. 18A.)

Entries are timbered with three-piece sets, and the roof in rooms is supported by props placed on 6-foot centers.

The coal is cut in the bottom of the bed by shortwall mining machines equipped with 8-foot cutter bars. Water is used on the cutter bars. The practice of sprinkling broken coal also is followed. The coal is drilled with electric auger drills. One row of eight holes is drilled 2 feet below the top of the bed. Each of the two rib holes is charged with three sticks of permissible explosive, and the remaining holes with two sticks each. The explosives are fired electrically during the shift. Approximately 5.5 tons of coal is produced per pound of explosive.

In the operation of a unit (two rooms), one room is prepared while the coal is loaded in the second room. After the room is cut, flat steel plates are placed along the face of the room to facilitate shoveling the coal to shaking conveyors.

Room conveyors, which are the shaking type, are placed on the lower side of each room. The drives of these conveyors have recently been changed from compressed air to electricity. The coal is conveyed by the shaking conveyor to a retarding chain conveyor placed in the inby panel entry. This conveyor transports the coal to cars on the cross entry. End-dump steel cars having a rated capacity of 3 tons are loaded with an average of 3 tons of coal. They are transported to the slope parting by 8-ton trolley locomotives and are hoisted up the slope to the surface in seven-car trips.

The mining cycle in a two-room unit is (1) timber, (2) undercut, (3) drill and load holes, (4) place steel plates at face, (5) extend conveyors, (6) blast, and (7) load coal.

The average crew of men assigned to a unit (two rooms) is:

Cutting-machine operator	1
Cutting-machine helper	1
Drillers to drill and shoot, timber, extend pan lines, and prepare place for loading	2
Loaders	5
Clean-up man on panel entry and chain conveyor	1
Sprinkler and rock-duster[1]	1/2
Car trimmer[1]	1/2
Total	11

[1] There are usually two units in a panel.

Pillar Extraction

Extraction of pillars is started in the two inby rooms of the panel after the panel has been developed. Room pillars are 70 feet long and 40 feet wide, and these are split in the center by a crosscut driven at right angles to the longitudinal center line of the pillar. (See fig. 18B.) This crosscut is 30 feet wide, and when completed there are two blocks of coal, each 20 feet long and 40 feet wide, in place at each end of the pillar. Steel plates are placed on the floor of the crosscut to provide a smooth surface on which to push and shovel coal to the shaking conveyor at the lower side of the outby room. The mining of the inby end of the pillar is followed by mining the outby end, and this operation completes the extraction of the pillar. A small amount of coal in one corner of each of the end pillars is not recovered. Chain pillars in the panel entries are the same size and are extracted by the same system used in recovering room pillars.

Classification of Employees

Classification	Shift			Total
	1st	2d	3d	
Underground - mechanized units:				
Cutting-machine men	3	2	1	6
Cutting-machine helpers	3	2	1	6
Drillers and shooters	6	4	2	12
Coal loaders	15	10	5	30
Clean-up men	3	1	1/2	4-1/2
Sprinklers and rock-dusters	2	1	1/2	3-1/2
Car trimmers	2	1	1/2	3-1/2
Total	34	21	10-1/2	65-1/2
Other underground employees:				
Motormen	2	1	1/2	3-1/2
Ventilation man	1	-	-	1
Timbermen	2	1	1	4
Rope riders	1	1	1	3
Development (rock and coal)	18	-	-	18
Foremen	2	1	1	4
Total	26	4	3-1/2	33-1/2
Total underground employees	60	25	14	99

Classification	Shift			Total
	1st	2d	3d	
Surface employees:				
Hoisting engineers	1	1	1	3
Motormen	1	1	-	2
Weighmen	1	1	-	2
Shop and repairmen	8	2	-	10
Tipplemen	10	10	-	20
Handymen	1	1	1	3
Total	22	16	2	40
Total employees	82	41	16	139

Summary

Percent of mine mechanized	100
Average daily production, raw coal, tons	700
Average daily production, raw coal, tons, room-and-pillar	650
Average daily production, raw coal, tons, development	50
Number of mechanized units (2 conveyors)	3
Number of mechanized units, shifts per day	6
Number of conveyors	6
Number of conveyor shifts per day	12
Average production per unit (2 conveyors) per shift, tons	108.3
Average production per conveyor per shift, tons	54.2
Average number of men on mechanized units, room-and-pillar	65.5
Average number of men per unit per shift, room-and-pillar	10.9
Average production per man per shift on mechanized units, tons	9.9
Total employees, underground	99
Average production per man per shift, underground, tons	7.1
Total employees, underground and surface	139
Average production per man employed per shift, tons	5.1

For comparison, operating data showing performance of mechanized equipment at mines described in this report are summarized in tables 1 and 2. Table 1 is a summary of mobile loading-machine performance, and table 2 summarizes the performance of conveyor units.

TABLE 1. - Summary of performance, mobile loading units

		Mine						
		46	47	48	49	50	52	53
1.	Description of mechanization:							
	a. Cutting machines	Track-mounted and rubber-tired	Track-mounted	Rubber-tired	Rubber-tired	Shortwall	Shortwall	Shortwall
	b. Loading machines	Mobile crawler-mounted	Mobile track-mounted	Mobile track- and crawler-mounted	Mobile crawler-mounted	Mobile crawler-mounted	Mobile crawler-mounted	Mobile crawler- and track-mounted
	c. Machines load into	Shuttle cars and mine cars	Mine cars	Shuttle cars and mine cars	Shuttle cars	Shuttle cars	Shuttle cars	Shuttle cars and mine cars
2.	Location of mine	Pennsylvania	Pennsylvania	West Virginia	West Virginia	Pennsylvania	Pennsylvania	West Virginia
3.	Mechanization of mine, percent	100	100	100	100	100	100	50
4.	Average daily production, tons	3,400 tons raw coal 2,725 tons clean coal	4,390 tons raw coal 3,950 tons clean coal	7,500	2,730	1,800	2,100	[2] 3,480 tons raw coal 2,400 tons clean coal
5.	Thickness and dip of bed	100 inches, flat	84 inches, flat	102 inches, flat (90 inches mined)	100 inches, flat (88 inches mined)	42 inches, flat	38 inches, flat	54 to 66 inches, flat
6.	Number and hours of shifts, underground	3 - 9-hour	3 - 9-hour	2 - 8-hour	3 - 8-hour	2 - 9-hour	3 - 9-hour	2 - 8-hour
7.	Number and hours of shifts, surface	2 - 9-hour	2 - 9-hour	2 - 8-hour	2 - 8-hour	2 - 9-hour	2 - 9-hour	2 - 8-hour
8.	Number units	9	6	10	3	6	[1] 8	12
9.	Unit-shifts per day	25	18	22	9	13	22	24
10.	Average production per unit per shift, tons	136 (raw coal)	244 (raw coal)	341	303	138.4	95.5	145 (raw coal) 100 (clean coal)
11.	Average number of men per unit per shift	7.5	14.5	17	18	10	8	10
12.	Man-shifts per day on mechanized units	188	261	375	162	130	174	230
13.	Average production per man per shift, mechanized units, tons	18.1 (raw coal)	16.8 (raw coal)	20	16.9	13.8	12.1	15.1 (raw coal) 10.4 (clean coal)
14.	Total number of employees, underground	272	369	521	230	216	236	400
15.	Average production per man per shift, underground, tons	12.5 (raw coal)	11.9 (raw coal)	14.4	11.9	8.3	8.9	8.7 (raw coal) 6.0 (clean coal)
16.	Total number of employees, surface and underground	342	441	649	296	269	285	[3] 542 mechanized mining
17.	Average production per shift per man employed, tons	9.9 (raw coal) 8.0 (clean coal)	9.9 (raw coal) 9.0 (clean coal)	11.6	9.6	6.7	7.4	6.4 (raw coal))[4] mechanized 4.5 (clean coal)) mining
18.	Average production of coal per pound of explosives, tons	7.8	2.5	-	-	3.8	7.3	3
19.	Average production of coal per prop, tons	7.5	-	-	-	3.5	-	-
20.	Average production of coal per crossbar	50.0	-	25	27	-	-	20
21.	Size of mine cars, tons	3.3	7.5	10	3	1.5	4	5
22.	Estimated recovery, panels, percent	90 to 95	93	87	85	88	95	92
23.	Estimated recovery, over-all, percent	72	-	75	-	-	75 to 80	-

[1] Six mobile loading machine units, two conveyor units.

[2] Daily coal mined mechanically reported, total daily production, 5,810 tons raw coal, 4,800 tons clean coal.

[3] Total employees, 1,068 including hand loaders.

[4] Production per man employed, 5.4 raw coal, 4.5 clean coal.

TABLE 2. - Summary of performance of conveyor units

		Mine		
		51	54	55
1.	Description of mechanization:			
	a. Cutting machines	Special top cutter	Shortwall	Shortwall
	b. Conveyors, type	Chain and shaking	Chain and shaking	Chain and shaking
	c. Conveyors load into	Mine cars	Belt conveyors	Mine cars
2.	Location of mine	Pennsylvania	Wyoming	Wyoming
3.	Mechanization of mine, percent	70	100	100
4.	Average daily production, tons	500	1,100	700
5.	Thickness and dip of bed	28 inches, flat	9 to 16 feet - 23 degrees	60 to 64 inches - 20 degrees
6.	Number and hours of shifts, underground	3 - 9-hour	3 - 7-hour	3 - 7-hour
7.	Number and hours of shifts, surface	1 - 9-hour	2 - 7-hour	2 - 7-hour
8.	Number units	2 - 2 conveyors each shift	3 in rooms - 2 in entries	3
9.	Unit-shifts per day	6 - 2 conveyors each shift	6 in rooms - 6 in entries	6
10.	Average production per unit per shift, tons	62.5 - 31.25 per conveyor shift	150 in rooms - 33 in entries	108.3 per unit 54.2 per conveyor
11.	Average number of men per unit per shift	10	15 in rooms - 5 in entries	11
12.	Man-shifts per day, mechanized units	60	105	65.5
13.	Average production per man per shift, mechanized units, tons.	6.3	10.5	9.9
14.	Total number of employees, underground	82.4 (mechanized mining)	13.5	99
15.	Average production per man per shift, underground, tons	4.6	8.1	7.1
16.	Total number of employees, surface and underground	97.8 (mechanized mining)	156	139
17.	Average production per shift per man employed, tons	3.8 (mechanized mining)	7.1	5.1
18.	Average production of coal per pound of explosives, tons	7	4.7	5.5
19.	Average production of coal per prop, tons	2	8	72
20.	Average production of coal per crossbar	-	-	144
21.	Size of mine cars, tons	1	5	3
22.	Estimated recovery, panels, percent	80 to 85	-	-
23.	Estimated recovery, over-all, percent	-	-	-

EXPLANATION OF CURVES

The following curves are based upon detailed studies of mechanized mining in more than 50 coal mines in every important coal field in the United States. The studies include loading practices with mobile loading devices, conveyors equipped with self-loading heads, and hand-loading on chain and shaking conveyors.

The points on which the curves are based were determined by computing weighted average production and man-hours for groups of mines operating under similar physical conditions. Therefore, the curves represent the average man-hours per ton and production for various bed thicknesses. Operating data at any one mine might deviate above or below points on the curves, but in planning new operations it can be expected that production and man-hours per ton for various bed thicknesses with the several types of loading equipment will be reasonably near the curves.

In computing man-hours per ton and production per mechanized unit per hour, the total hours in the shift worked were used. An employee may actually work only 6 hours at the face, but the number of hours in the shift worked (7, 8, or 9) was used in all computations to obtain man-hours per ton and output per unit per hour.

Figure 19:

Relation of man-hours per ton of raw coal produced to the thickness of the coal bed (or portion of bed mined) for labor employed at the face on mobile loading units, and total labor employed underground for mines practicing pillar extraction. An example of the man-hours required to produce a ton of coal in a bed 72 inches thick, using mobile loading machines and extracting pillars, follows:

	Man-hours per ton
Total labor underground, raw coal	0.77
Surface labor, raw coal	1/ .17
Total labor, raw coal	.94
Total labor, clean coal	2/ 1.11
Add 10 percent for idle time	.11
Total labor	1.22

1/ Weighted average surface labor, in man-hours, for mines studied.

2/ Estimated average refuse at cleaning plant, 15 percent of raw coal.

Figure 20:

Relation of man-hours per ton of raw coal produced to the thickness of the coal bed (or portion of bed mined) for labor employed at the face on mobile loading units and total labor employed underground for mines not extracting pillars. An example of the man-hours required to produce a ton of coal in a

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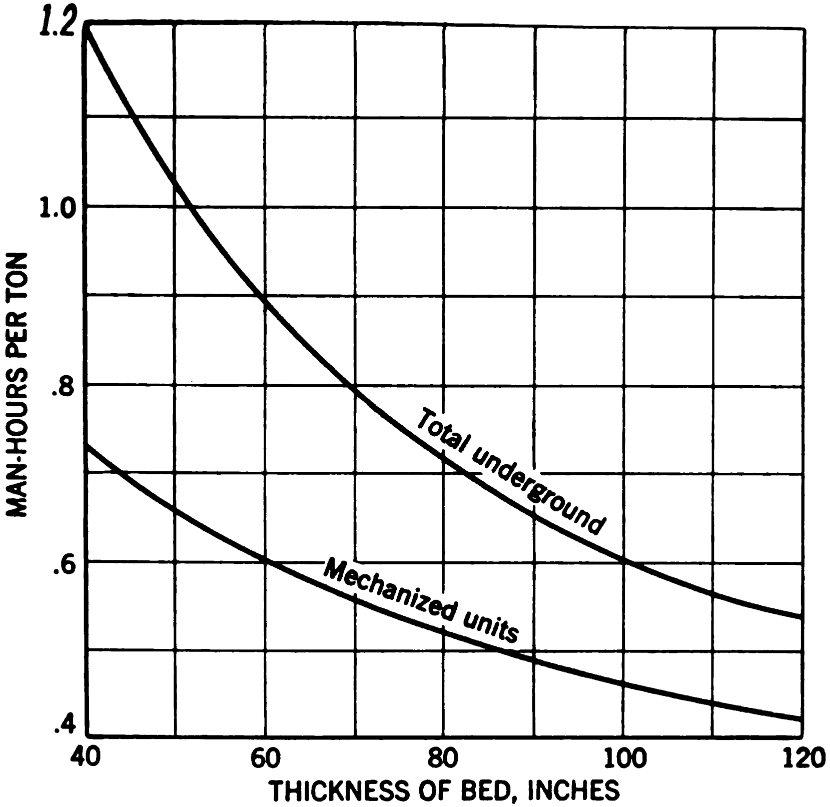

Figure 19. - Relation of man-hours per ton of raw coal to thickness of bed. Pillars extracted. Mobile loading machines. (Man-hours computed from full 7-, 8-, or 9-hour shifts.)

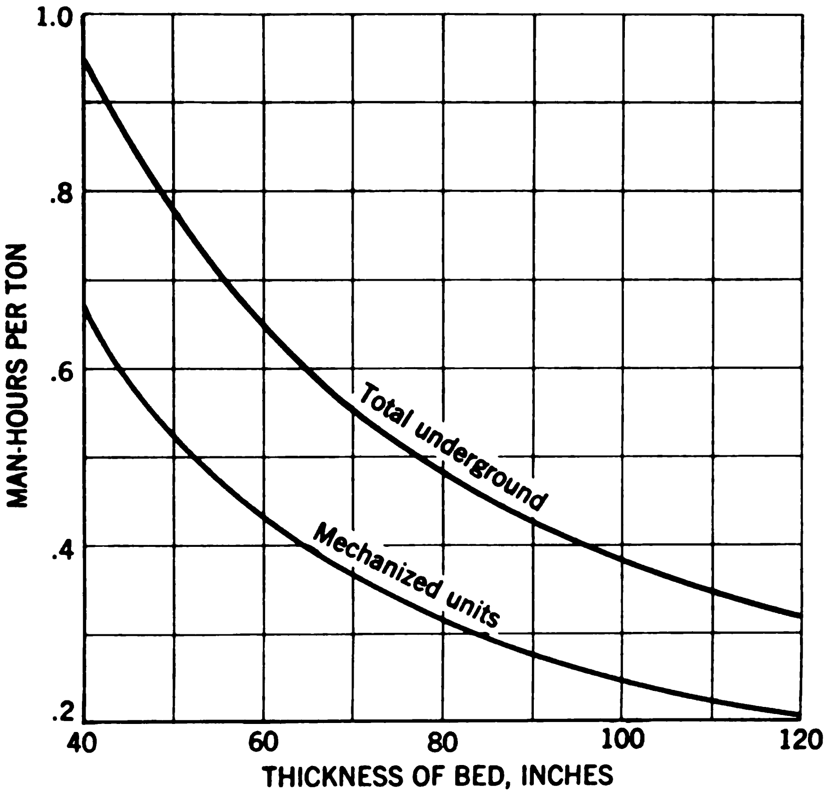

Figure 20. - Relation of man-hours per ton of raw coal to thickness of bed. Pillars not extracted. Mobile loading machines. (Man-hours computed from full 7-, 8-, or 9-hour shifts.)

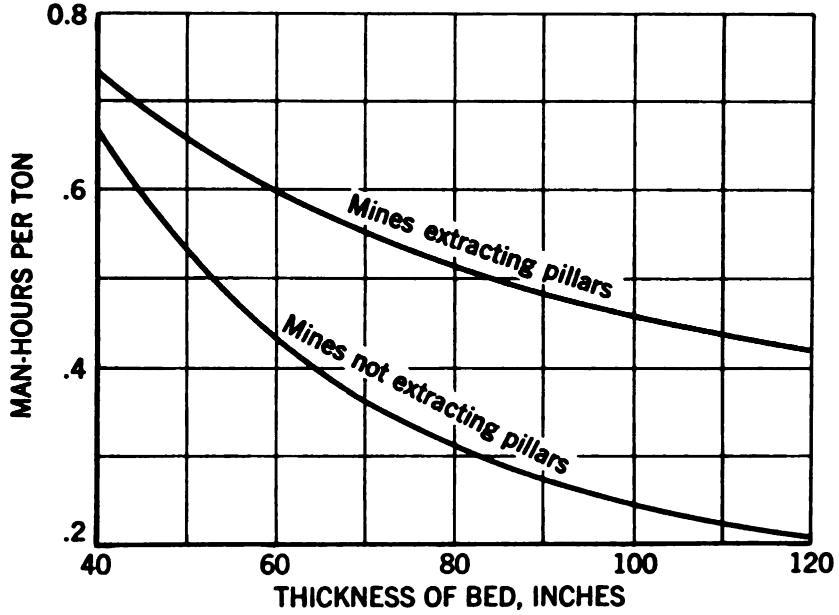

Figure 21. - Relation of man-hours per ton on mechanized units to thickness of bed. Pillars extracted and pillars not extracted. Mobile loading machines. (Man-hours computed from full 7-, 8-, or 9-hour shifts.)

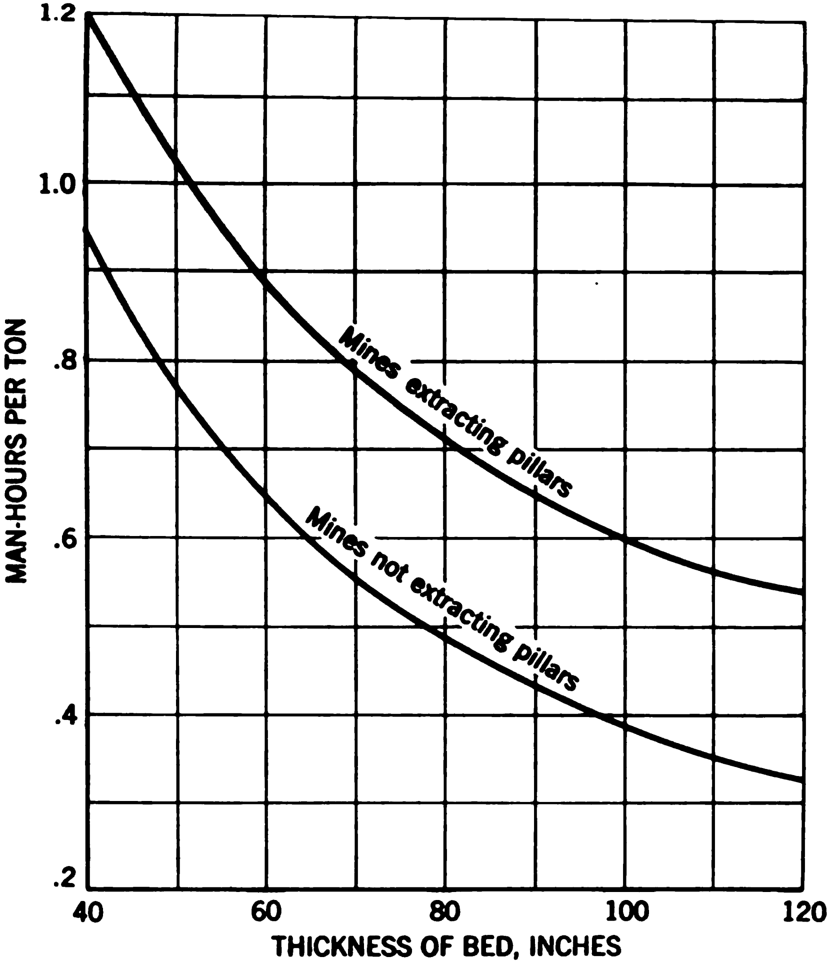

Figure 22. - Relation of man-hours per ton from total underground labor to thickness of bed. Pillars extracted and pillars not extracted. Mobile loading machines. (Man-hours computed from full 7-, 8-, or 9-hour shifts.)

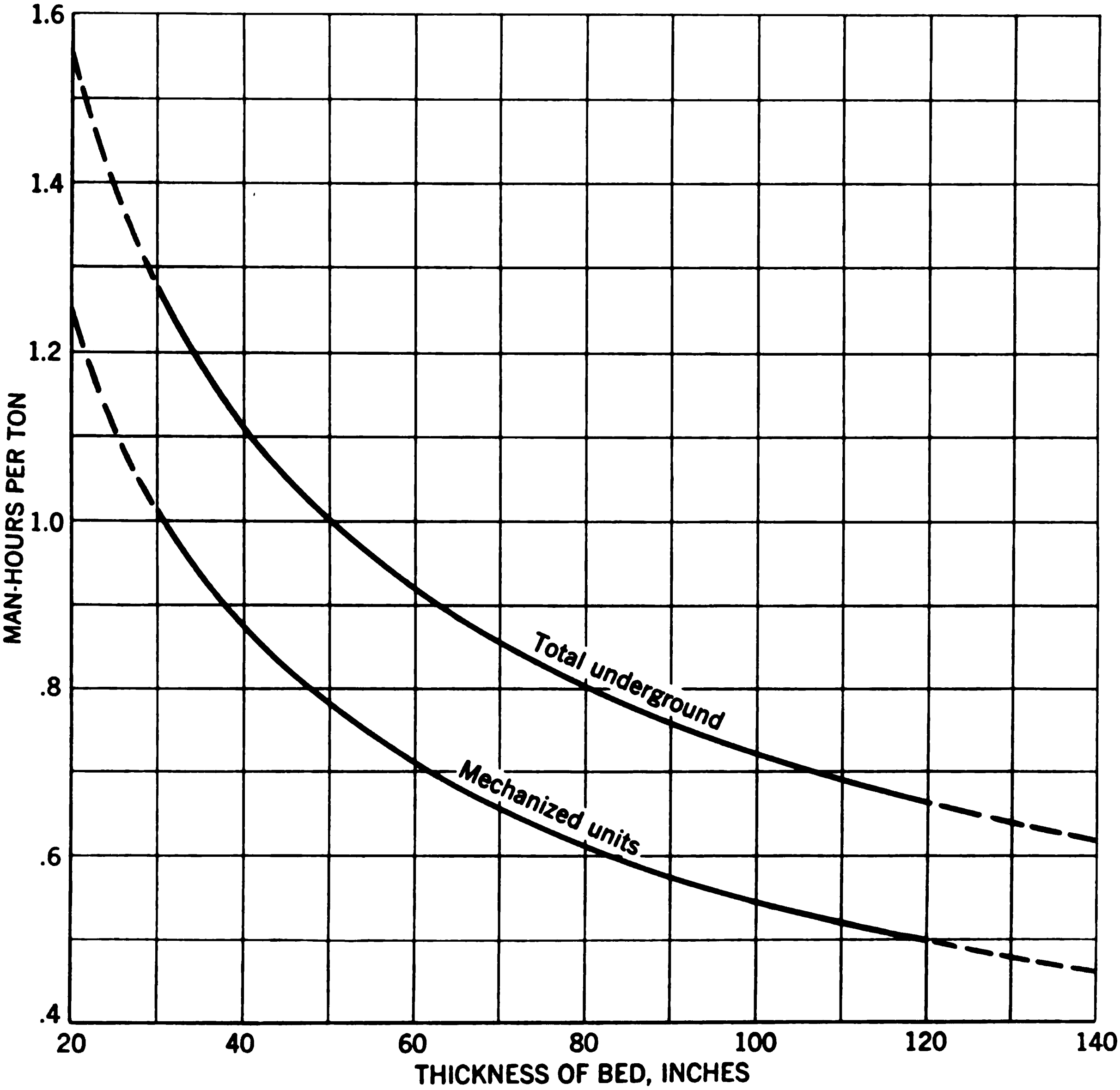

Figure 23. - Relation of man-hours per ton of raw coal to thickness of bed. Pillars extracted. Conveyors. (Man-hours computed from full 7-, 8-, or 9-hour shifts.)

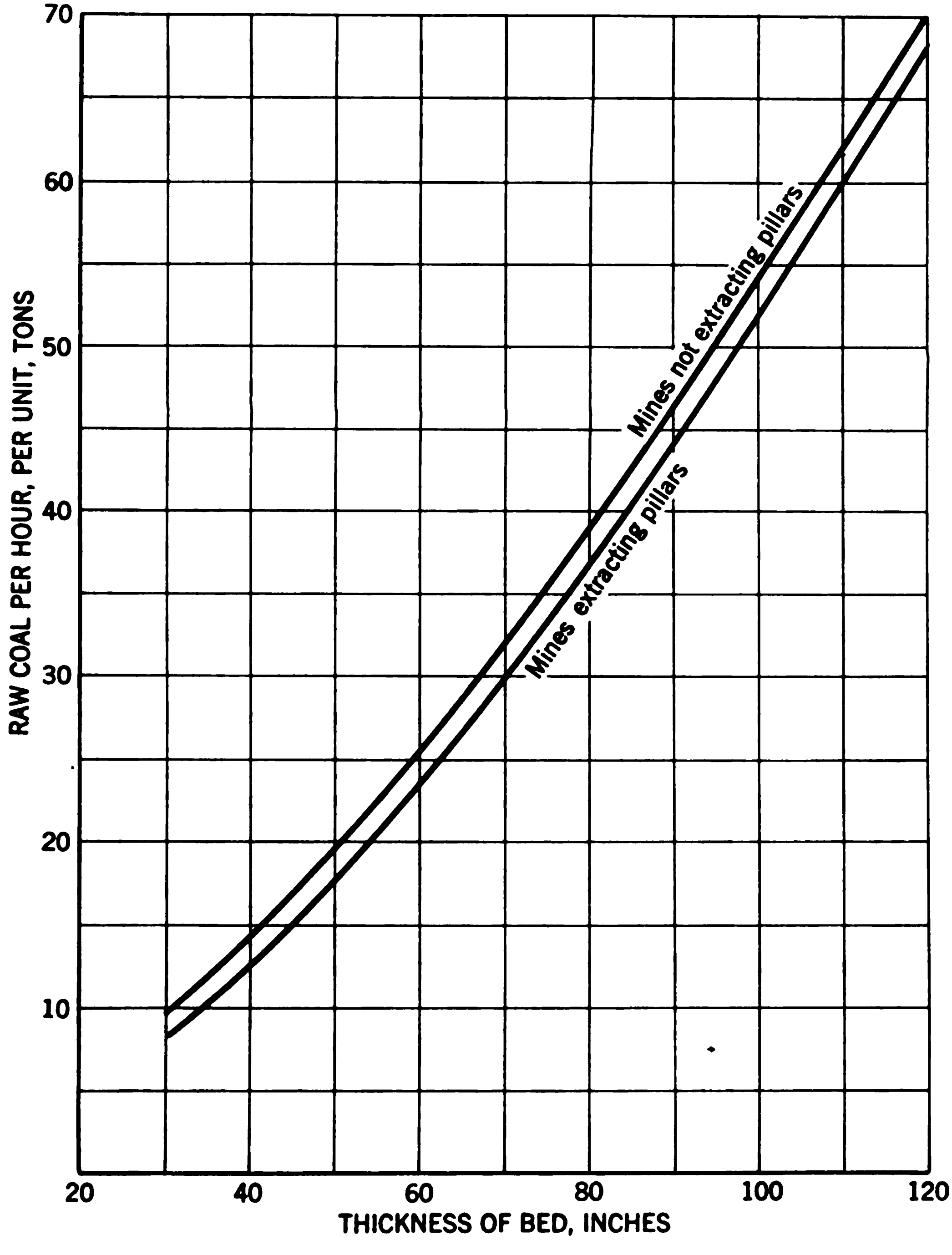

Figure 24. - Relation of tons of raw coal loaded per mobile loading unit per hour to thickness of coal bed. Pillars extracted and pillars not extracted. (Tons per hour computed from full 7-, 8-, or 9-hour shifts.)

bed 72 inches thick, using mobile loading machines, where pillars are not extracted, follows:

	Man-hours per ton
Total labor underground, raw coal	0.54
Surface labor, raw coal	[1].17
Total labor, raw coal	.71
Total labor, clean coal	[2].84
Add 10 percent for idle time	.09
Total labor	.93

[1] Weighted average surface labor, in man-hours, for mines studied.

[2] Estimated average refuse at cleaning plant, 15 percent of raw coal.

Figure 21:

The relation of man-hours per ton on mechanized units using mobile loading machines to thickness of coal bed at mines practicing pillar extraction and at mines where pillars are not extracted. These curves show that man-hours per ton at the face are higher at mines where pillars are extracted than where pillars are not extracted. The difference in man-hours per ton increases as the thickness of the coal bed increases and ranges from 0.09 man-hour per ton for a bed 42 inches thick to 0.21 man-hour per ton for a bed 120 inches thick. Roof control generally is a greater problem where pillars are extracted, and the difference in man-hours per ton shown on the curves is due to additional time spent in timbering to protect the roof in operating sections. More men are required to set timbers where beds are thick than where thin beds are mined.

Figure 22:

The relation of man-hours per ton for total underground labor using mobile loading machines to thickness of coal bed at mines practicing pillar extraction and at mines where pillars are not extracted. Total labor employed underground ranges from 0.22 to 0.25 man-hour per ton more at mines extracting pillars than where pillars are not extracted.

Figure 23:

Relation of man-hours per ton of raw coal produced to the thickness of the coal bed (or portion of bed mined) for labor employed at the face on conveyor units, and total labor employed underground for mines practicing pillar extraction. An example of the man-hours required to produce a ton of coal in a bed 42 inches thick, using conveyors and extracting pillars, follows:

	Man-hours per ton
Total labor underground, raw coal	1.04
Surface labor, raw coal	[1].20
Total labor, raw coal	1.24

See footnote at end of table on following page.

	Man-hours per ton
Total labor, clean coal	[2]1.46
Add 10 percent for idle time	.15
Total labor	1.61

[1] Weighted average surface labor, in man-hours, for mines studied.

[2] Estimated average refuse at cleaning plant, 15 percent of raw coal.

Figure 24:

Relation of tons of raw coal loaded per mobile loading unit per hour to thickness of coal bed at mines practicing pillar extraction and at mines where pillars are not extracted. These curves show the small difference in coal loaded per hour in pillar extraction and where pillars are not extracted. This difference is about 2 tons per hour for all bed thicknesses. For example, in a 72-inch bed production per loading machine per hour, where pillars are extracted, will be about 7 percent less than in mines where pillars are not recovered.

Figure 25:

Relation of tons of raw coal loaded per conveyor per hour to thickness of coal bed at mines practicing pillar extraction. Only a few conveyor operations where pillars were not extracted were studied, but the little information obtained indicates that the production per conveyor per hour is about the same whether pillars are or are not extracted.

GENERAL CONCLUSIONS

1. Roof Control.

This study indicates clearly that the most difficult problem encountered in extracting pillars with mechanized equipment is the effective control of not only the immediate roof but the entire overlying strata. The speed and regularity with which pillars are extracted help to obtain regular breaks in overlying strata along established pillar lines, thus relieving the weight at the coal faces. Many mines take advantage of natural cleats in roof rock to obtain frequent and systematic roof falls. Although roof-control problems in coal mining have been studied for many years, much research remains to be done on roof control and subsidence.

2. Production.

The production per mobile loading machine is 6 to 10 percent less in pillar mining than where pillars are not recovered. Production per conveyor per hour seems to be about the same in pillar and non-pillar mining.

3. Costs.

Studies show that labor employed underground at mines using mobile loading devices ranges from 0.22 to 0.25 man-hour per ton more in pillar mining

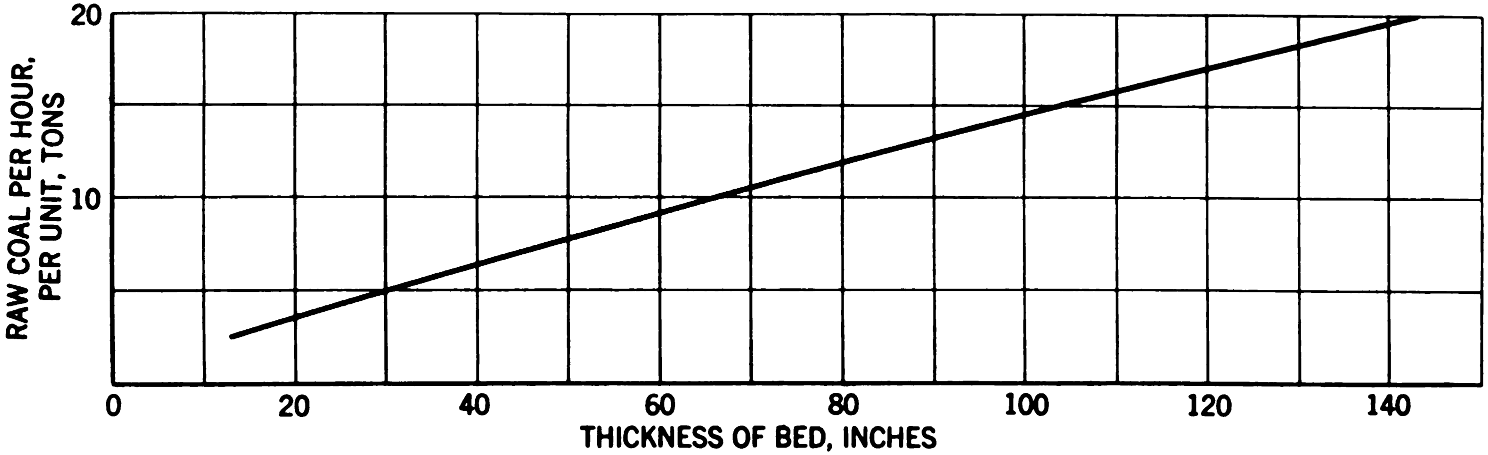

Figure 25. - Relation of tons of raw coal loaded per conveyor per hour to thickness of coal bed. Pillars extracted. (Tons per hour computed from full 7-, 8-, or 9-hour shifts.)

than in non-pillar mining. However, there are other factors that tend to offset this higher labor cost. Some of these are:

a. Smaller initial capital investment per ton in shafts, slopes, surface plants, haulage and airways, track, trolley, and power-transmission lines, because greater tonnages are recovered from the areas mined.

b. More tons recovered per acre; therefore, less depletion per ton, and where high real estate taxes on land owned over a period of years have been paid the tax cost per ton of coal produced will be less.

4. Percentage of recovery.

The benefits in the conservation of a valuable natural resource through the practice of pillar extraction are obvious. This is particularly important to the country's economy in areas of high-quality coals that are suitable for metallurgical or special purposes other than steam or space heating. It is claimed by some that the transition from hand-loading to mechanical loading was accompanied by lower percentage of recovery in mines practicing mechanized mining. This is not borne out at the mines studied, where mechanical extraction of pillars is practiced. The tendency to more nearly mine the entire thickness of the coal bed is increasing, and the over-all percentage of coal recovered has been increased by the introduction of mechanical cleaning. Mine 46 is a good example of increased percentage of recovery over hand methods. Under hand-loading methods, selective mining was practiced and only 58 inches of the bed was mined. The portion mined was 59 percent of the 99-inch total thickness. At present, the entire bed is mined, and the percentage of recovery has been greatly increased.

The practice of extracting pillars increases the percentage of recovery of coal in a given area, and if more mines can be encouraged to adopt this practice the over-all percentage of recovery in coal mining will improve. Therefore, the study of extraction of pillars with mechanized equipment is of paramount importance in the conservation of a valuable natural resource and will be continued.